Radiological Health Data

VOLUME IV, NUMBER 9

SEPTEMBER 1963

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis and interpretation of data on environmental radiation levels. The Department delegated this responsibility to the Division of Radiological Health, Public Health Service.

Radiological Health Data is published by the Public Health Service on a monthly basis. Data are provided to the Division of Radiological Health by other Federal agencies, State health departments, and foreign governments. Pertinent original data and interpretive papers are invited from investigators. Accepted material will be appropriately credited. The reports are reviewed by a Board of Editorial Advisors with representatives from the following Federal agencies:

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For further information on any subject reported in this issue, readers are referred to the contributors indicated in article headings.

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Fission Product Beta Activity in Airborne Particulates and Precipitation

Early indications of possible fission product activity fluctuations in other phases of the environment are being secured through the continuous surveillance of gross beta activity in air and precipitation. The information obtained through this form of surveillance does not by itself permit evaluation of biological effects due to fallout, but it does form the basis for an alerting system and can be used as a guide for determining when and where more extensive monitoring of radioactivity in food, milk, and water is desirable.

In this section, gross beta concentrations for May 1963 are presented in reports from the Radiation Surveillance Network and the Canadian Radioactive Fallout Study Program. Network intercalibration factors, determined by Lockhart and Patterson (*1*), were used in constructing the isogram map (fig 4), which presents data on Canadian and U.S. gross beta radioactivity in air for April. To adjust the data from the two networks to a common baseline, the U.S. data were multiplied by a factor of 1.54, the U.S.-Canadian intercalibration factor suggested by the NRL study. Also included are air data collected by the Pan American Sampling Program during the period November 1962–May 1963.

REFERENCE

(*1*) Lockhart, L. B. Jr., and R. L. Patterson, Jr.: *Intercalibration of Some Systems Employed in Monitoring Fission Products in the Atmosphere, NRL Report 5850*, Washington, D.C. (November 13, 1962); abstracted in *Radiological Health Data*, December 1962.

RADIATION SURVEILLANCE NETWORK May 1963

Division of Radiological Health, Public Health Service

The Radiation Surveillance Network (RSN) comprises 72 sampling stations distributed throughout the United States (see figure 1). Most of these stations are manned by State health department personnel.

Air

Daily 24-hour air samples are collected on a 4-inch diameter, carbon-loaded cellulose dust filter in a high-volume air sampler. Field estimates of the gross beta activity of airborne particulates are derived by comparing portable survey meter readings of these filters with readings taken from a Sr^{90}–Y^{90} source of known activity. This determination is usually made about 5 hours after the end of the sampling period to eliminate interference from naturally occurring radon daughters. The Network's station operators report their field estimates daily by telephone to the Radiation Surveillance Center, Division of Radiological Health, Washington, D.C. From this information, a daily national report is prepared.

The filters are then forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, for a more refined measurement using a thin-window, gas-flow proportional counter, calibrated with a 40,000-pc Sr^{90}–Y^{90} standard. Each filter is counted at least 3 days after the end of the sampling period and is re-counted 7 days later. The initial 3-day aging of the sample eliminates interference from naturally occurring radon and thoron daughters. From the two counts, which are separated by the 7-day interval, it is possible to estimate the age of fission products and to extrapolate the activity to the time of collection. The extrapolation is performed by using the Way-Wigner formula: $AT^{1.2} = \text{constant}$ (*1*) [1] the daily

[1] In this expression, A is the activity and T is the time after fission product formation.

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS, MAY 1963

concentrations and estimated age are reported by the PHS in a monthly RSN report (*2*).

The average fission product beta concentrations in surface air during May 1963, as determined by laboratory analysis and extrapolated to the time of collection, are given in table 1. These data (adjusted by the intercalibration factor 1.54), [2] together with corresponding Canadian data, are represented by isogram lines in figure 4 which show the distribution of fission product activity over most of North America.

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meters. A 500-ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory to be counted by the same method used for analyzing the air samples, including extrapolation to the time of collection. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made. May 1963 averages of gross beta activity in precipitation, expressed in picocuries per liter (cp/liter) and nanocuries per square meter (nc/m^2), are presented in table 2.

Profiles

The profiles of the monthly average fission product beta activity in airborne particulates for each RSN station covering the period of time from the formation of the network in 1956 to the end of 1960 were published in *RHD*, July 1961. The profiles of 7 stations, from 1957 through May 1963, are shown in figure 2.

[2] See reference (*1*) on page 431.

REFERENCES

(*1*) Way, K., and E. P. Wigner: The Rate of Decay of Fission Products, *Physics Review, 73:* 1318–30 (June 1948).
(*2*) Radiation Surveillance Network: *Monthly Tabulation of Findings*, Division of Radiological Health, Public Health Service, Washington 25, D.C. (Distribution by official request).

TABLE 1.—FISSION PRODUCT GROSS BETA ACTIVITY IN SURFACE AIR, RSN, MAY 1963

[Concentrations in pc/m³]

Station location		Number of samples	Maximum	Minimum	Average[a]
Alaska:	Adak	31	10	<0.10	2.4
	Anchorage	30	8.2	0.36	3.0
	Attu	31	11	0.14	4.0
	Fairbanks	23	12	0.61	4.2
	Juneau	26	15	0.40	4.7
	Kodiak	29	9.2	0.10	2.41
	Nome	18	6.8	0.10	2.2
	Point Barrow	18	9.1	1.6	3.7
	St. Paul Island	28	5.5	<0.10	2.0
Ariz:	Phoenix	30	17	4.9	9.7
Ark:	Little Rock	29	15	5.3	9.7
Calif:	Berkeley	29	8.2	0.44	3.7
	Los Angeles	22	16	1.7	6.0
Colo:	Denver	27	22	1.8	9.2
Conn:	Hartford	30	12	1.5	5.8
Del:	Dover	22	15	1.7	8.1
D.C:	Washington	31	11	2.1	6.4
Fla:	Jacksonville	29	15	2.5	7.5
	Miami	26	13	2.8	7.0
Ga:	Atlanta	26	13	2.6	7.2
Guam:	Agana	12	4.9	<0.10	1.1
Hawaii:	Honolulu	29	9.9	1.6	3.7
Idaho:	Boise	30	17	1.0	9.6
Ill:	Springfield	29	11	1.4	6.1
Ind:	Indianapolis	27	18	0.84	7.5
Iowa:	Iowa City	28	12	0.71	5.4
Kans:	Topeka	30	11	3.3	6.8
Ky:	Frankfort	30	13	2.4	6.9
La:	New Orleans	31	12	3.2	7.1
Maine:	Augusta	30	16	1.8	6.9
	Presque Isle	31	12	1.1	6.0
Md:	Baltimore	22	8.5	2.3	5.2
	Rockville	15	12	2.0	6.2
Mass:	Lawrence	30	14	2.1	7.1
	Winchester	27	19	1.7	7.9
Mich:	Lansing	31	13	0.54	7.6
Minn:	Minneapolis	30	13	0.18	6.2
Miss:	Jackson	29	12	3.3	7.4
	Pascagoula	19	13	2.2	7.3
Mo:	Jefferson City	30	11	0.90	5.7
Mont:	Helena	30	14	1.8	7.3
Nebr:	Lincoln	19	17	1.2	6.0
Nev:	Las Vegas	28	29	6.1	14
N.H:	Concord	21	18	1.9	8.5
N.J:	Trenton	31	11	1.5	5.8
N. Mex:	Santa Fe	31	14	1.6	7.1
N.Y:	Albany	29	11	1.1	6.5
	Buffalo	17	17	2.3	8.9
	New York	18	12	1.6	5.3
N.C:	Gastonia	31	11	2.1	6.6
N. Dak:	Bismarck	30	13	0.25	6.5
Ohio:	Cincinnati	22	10	1.1	6.5
	Columbus	30	16	2.1	7.4
	Painesville	29	22	2.0	9.6
Okla:	Oklahoma City	31	9.3	4.5	6.2
	Ponca City	29	8.7	2.2	4.7
Ore:	Portland	29	24	3.4	9.4
Pa:	Harrisburg	27	11	1.4	5.2
P.R:	San Juan	29	4.5	0.72	2.6
R.I:	Providence	30	13	1.1	6.3
S.C:	Columbia	27	11	1.6	6.5
S. Dak:	Pierre	30	10	1.1	5.2
Tenn:	Nashville	30	18	1.8	8.5
Tex:	Austin	30	11	3.0	7.1
	El Paso	30	12	2.4	6.7
Utah:	Salt Lake City	31	15	2.3	8.1
Vt:	Barre	29	14	0.40	6.8
Va:	Richmond	31	11	1.8	5.4
Wash:	Seattle	31	9.8	1.0	4.3
W.Va:	Charleston	31	10	1.4	5.7
Wisc:	Madison	31	20	0.39	9.4
Wyo:	Cheyenne	29	12	3.6	7.5
Network			29	<0.10	6.37

[a] Averages are weighted by lengths of sampling times.

TABLE 2.—GROSS BETA ACTIVITY IN PRECIPITATION, RSN, MAY 1963

Station location		Average concentration (pc/liter)	Total deposition (nc/m²)
Alaska:	Anchorage	1,300	6
	Fairbanks	—[a]	—
	Juneau	1,400	100
Ark:	Little Rock	1,100	23
Calif:	Berkeley	580	5.8
	Los Angeles	—	—
Colo:	Denver	7,700	67
Conn:	Hartford	2,700	180
D.C:	Washington	3,600	110
Fla:	Jacksonville	2,400	100
	Miami	870	80
Ga:	Atlanta	—	—
Idaho:	Boise	2,400	61
Ill:	Springfield	920	39
Ind:	Indianapolis	2,200	100
Iowa:	Iowa City	2,600	120
Kans:	Topeka	2,200	230
Ky:	Frankfort	2,200	140
La:	New Orleans	1,600	27
Maine:	Augusta	1,900	200
	Presque Isle	1,500	110
Md:	Baltimore	3,600	36
Mass:	Lawrence	4,100	440
	Winchester	2,100	180
Mich:	Lansing	2,400	130
Minn:	Minneapolis	2,000	260
Miss:	Jackson	—	—
Mo:	Jefferson City	3,100	460
Mont:	Helena	3,200	100
Nebr:	Lincoln	2,700	140
Nev:	Las Vegas	—	—
N.J:	Trenton	2,700	119
N. Mex:	Santa Fe	2,300	29
N.Y:	Albany	2,100	64
	Buffalo	—	—
N.C:	Gastonia	890	49
N. Dak:	Bismarck	3,700	250
Ohio:	Columbus	2,000	110
	Painesville	3,200	130
Okla:	Oklahoma City	1,100	11
	Ponca City	1,400	86
Ore:	Portland	1,300	60
Pa:	Harrisburg	1,400	92
P.R:	San Juan	540	42
R.I:	Providence	2,100	260
S.C:	Columbia	3,200	45
S. Dak:	Pierre	2,100	34
Tenn:	Nashville	2,800	92
Tex:	Austin	2,300	66
	El Paso	—	—
Utah:	Salt Lake City	2,600	6.4
Vt:	Barre	2,700	120
Va:	Richmond	1,200	74
Wash:	Seattle	1,900	16
W.Va:	Charleston	2,100	180
Wisc:	Madison	2,500	93
Wyo:	Cheyenne	4,500	60

[a] Dash indicates no evaporated sample received.

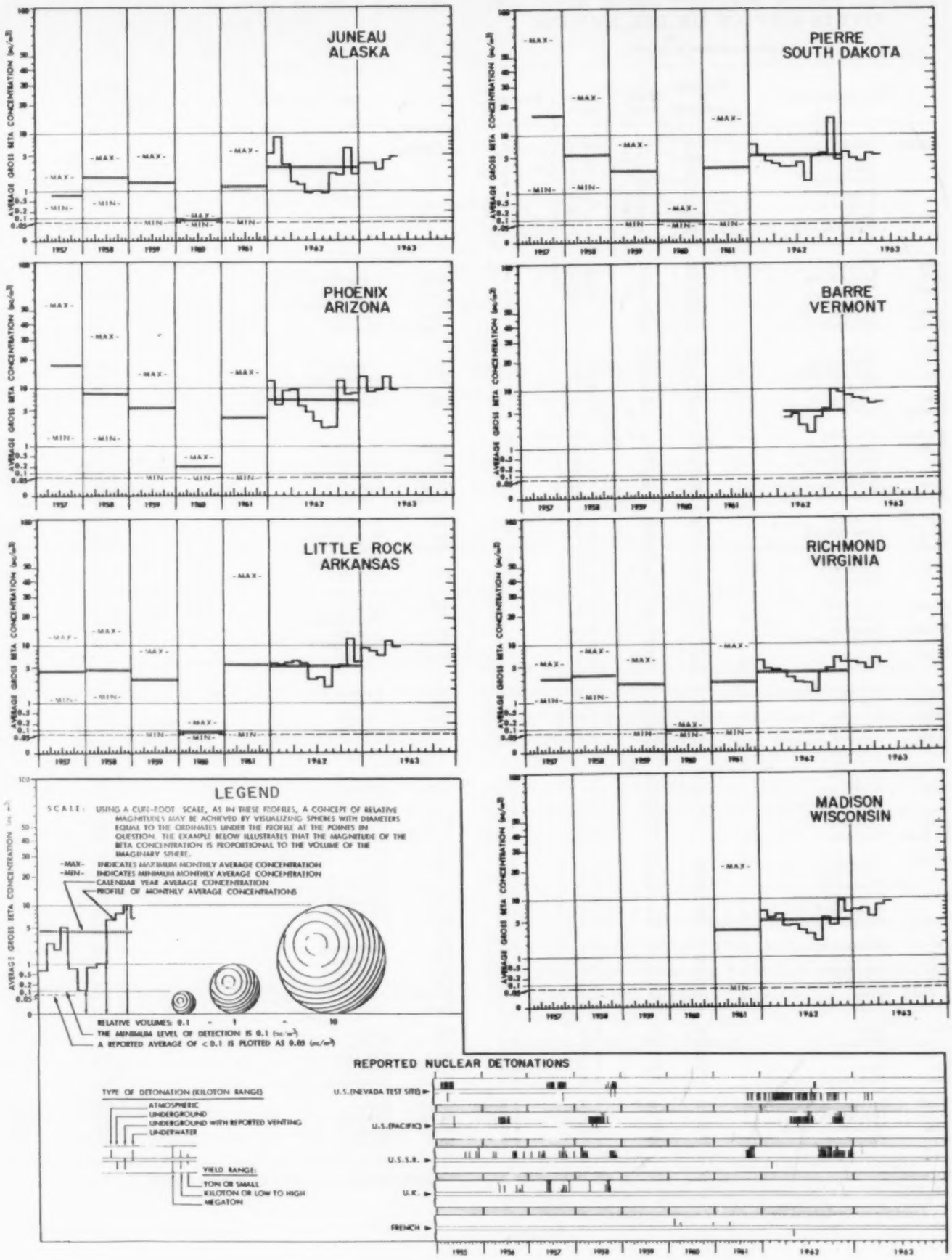

FIGURE 2.—MONTHLY AND YEARLY PROFILES OF BETA ACTIVITY IN AIR, RADIATION SURVEILLANCE NETWORK, 1957–May 1963

CANADIAN RADIOACTIVE FALLOUT STUDY PROGRAM
May 1963

Department of National Health and Welfare, Ottawa, Canada

As part of its Radioactive Fallout Study Program (RFSP), the Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation. Twenty-four RFSP collection stations are located at airports (see figure 3) where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

Air

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa. At the laboratory, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas flow Geiger-Mueller counter, system, calibrated with a Sr^{90}–Y^{90} standard. Four successive measurments are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for May 1963 are given in table 3 and presented in conjunction with U.S. adjusted air data by the isogram map (figure 4).

TABLE 3.—FISSION PRODUCT GROSS BETA ACTIVITY IN AIR, RFSP, MAY 1963

[Concentrations in pc/m³]

Station	Number of samples	Maximum	Minimum	Average
Calgary	31	24.3	4.6	13.8
Coral Harbour	31	15.5	0.9	6.7
Edmonton	31	27.0	6.0	11.9
Ft. Churchill	29	12.3	2.8	7.0
Ft. William	31	24.1	2.0	11.0
Fredericton	29	23.0	0.5	10.6
Goose Bay	31	15.7	2.4	9.2
Halifax	29	22.0	2.0	10.0
Inuvik	31	20.0	0.7	7.0
Montreal	31	28.0	3.0	15.8
Moosonee	31	24.0	1.2	11.8
Ottawa	31	23.0	1.3	14.2
Quebec	31	26.0	3.7	13.4
Regina	30	23.3	2.8	13.0
Resolute	30	12.9	3.5	7.4
St. John's	30	15.9	0.7	6.6
Saskatoon	31	26.0	2.5	13.5
Sault Ste. Marie	30	25.5	5.2	13.2
Toronto	31	21.5	0.2	11.8
Vancouver	31	24.1	2.9	9.8
Whitehorse	31	30.2	2.0	12.1
Windsor	31	25.2	2.7	13.0
Winnipeg	30	27.2	1.6	12.6
Yellowknife	30	21.0	2.2	11.2
Network		30.2	0.2	11.1

Precipitation

The amount of radioactive fallout deposited on the ground is determined from measurements on

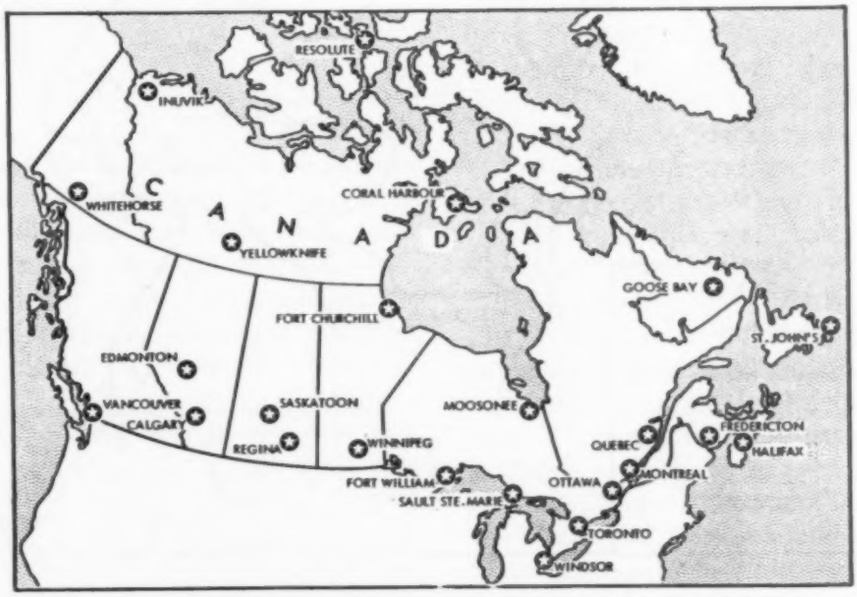

FIGURE 3.—CANADIAN AIR AND PRECIPITATION SAMPLING STATIONS, MAY 1963

TABLE 4.—FISSION PRODUCT GROSS BETA ACTIVITY IN PRECIPITATION, RFSP, MAY 1963

Station	Total beta activity	
	pc/liter	mc/km²
Calgary	[b]	86.3
Coral Harbour	[b]	116
Edmonton	5,890	190
Ft. Churchill	1,930	51.5
Ft. William	6,040	380
Fredericton	2,750	193
Goose Bay	2,490	123
Halifax	3,940	414
Inuvik	[b]	63.9
Montreal	2,640	233
Moosonee	3,580	311
Ottawa	2,620	200
Quebec	3,020	266
Regina	4,790	276
Resolute	680	36.2
St. John's	2,170	234
Saskatoon	4,670	194
Sault Ste. Marie	3,050	246
Toronto	2,970	206
Vancouver	1,315	60.1
Whitehorse	[a]	[a]
Windsor	3,800	238
Winnipeg	5,030	341
Yellowknife	[b]	52.5
Average	3,340	196

[a] No sample.
[b] Trace precipitation.

material collected in special polythene-lined rainfall pots. After transfer of the water to the sampling container, the polythene liner is removed, packed with the sample, and sent to the laboratory. May precipitation data for Canada are shown in table 4.

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(1) Bird, P. M., A. H. Booth, and P. G. Mar: *Annual Report for 1959 on the Radioactive Fallout Study Program, CNHW–RP–3*, Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) Bird, P. M., A. H. Booth, and P. G. Mar: *Annual Report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4*, Department of National Health and Welfare, Ottawa, Canada (December 1961).

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(4) Beale, J. and J. Gordon: *The Operation of the Radiation Protection Division Air Monitoring Program, RPD–11*, Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) Booth, A. H.: *The Calculation of Maximum Permissible Levels of Fallout in Air and Water and Their Use in Assessing the Significance of 1961 Levels in Canada, RPD–21*, Department of National Health and Welfare, Ottawa, Canada (August 1962).

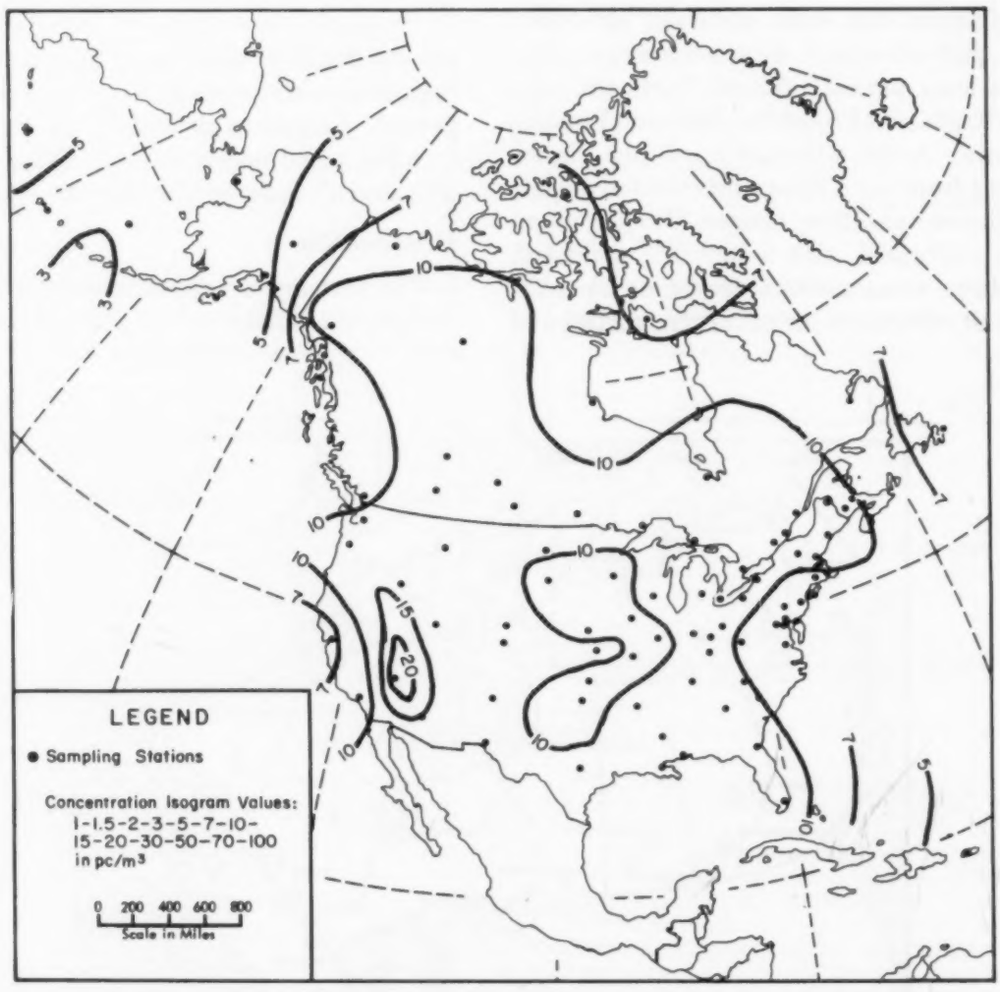

FIGURE 4.—AIRBORNE GROSS BETA CONCENTRATION ISOGRAM VALUES FOR CANADA AND THE U.S., MAY 1963

PAN AMERICAN SAMPLING PROGRAM
November–May 1963

Pan American Health Organization and Public Health Service

Gross beta activity in air is being monitored at three locations in the Americas under a collaborative radiological health program between the Pan American Health Organization (PAHO) and the Public Health Service (PHS).

The three air sampling stations presently included in the program are located in Santiago, Chile; Lima, Peru; and Caracas, Venezuela. The Caracas station was activated in November 1962 and the other two stations entered in December.

The air sampling stations are manned by local personnel and the sampling equipment and laboratory analyses are provided by the Public Health Service. Equipment and counting procedures are identical with those employed for the Radiation Surveillance Network.

Fission product gross beta activity for the months of November 1962 through May 1963 are presented in table 5.

The higher monthly average values noted for Caracas, in comparison with values for corresponding months for Lima and Santiago, are consistent with the Northern Hemisphere location of the Caracas station.

TABLE 5.—GROSS BETA ACTIVITY IN AIR, PASP

[Concentrations in pc/m³]

Sampling stations Months	No. of samples	Maximum	Minimum	Average
November 1962				
Caracas, Venezuela	20	6.3	0.11	1.2
December 1962				
Caracas, Venezuela	19	4.1	0.12	2.0
Lima, Peru	12	0.50	0.33	0.38
Santiago, Chile	15	0.41	0.14	0.26
January 1963				
Caracas, Venezuela	23	8.9	0.32	2.9
Lima, Peru	5	0.25	0.14	0.19
Santiago, Chile	14	0.41	0.18	0.27
February 1963				
Caracas, Venezuela	20	4.1	1.2	2.2
Lima, Peru	19	0.91	0.12	0.29
Santiago, Chile	15	0.35	0.15	0.24
March 1963				
Caracas, Venezuela	20	4.3	0.25	2.7
Lima, Peru	18	0.23	0.10	0.15
Santiago, Chile	14	0.67	0.16	0.30
April 1963				
Caracas, Venezuela	20	4.6	0.48	1.8
Lima, Peru	14	0.18	0.11	0.14
Santiago, Chile	16	0.29	0.12	0.18
May 1963				
Caracas, Venezuela	21	2.7	0.15	1.2
Lima, Peru	0	—	—	—
Santiago, Chile	10	1.1	0.13	0.27

Fission Product Gamma Activity in Airborne Particulates

THE 80TH MERIDIAN NETWORK
March and April 1963

William R. Collins Jr. [1]

This report covers the data available on gamma activity measurements performed on ground-level air filter samples collected during March and April 1963 from stations near the 80th Meridian (see figure 1). Through the end of March all stations in the Southern Hemisphere continued sampling about 1200 cubic meters of air per day on 8-inch-diameter cellulose asbestos (type 6) filter papers, using the method and equipment previously described by the Naval Research Laboratory.[2] Beginning on March 1 in the Northern Hemisphere and April 1 in the Southern, stations sampled about 1400 cubic meters of air per day on 8-inch-diameter polystyrene (Microsorban) filters using the new methods and equipment selected by Health and Safety Laboratory (HASL). The major changes that have been made in the equipment (see figure 2) are the addition of a pump pressure gage which permits a more accurate calculation of the effect of pressure drop on sample volume and the preset vacuum relief valve which automatically ends the sampling when the pump pressure exceeds 78 inches of water. Minor alterations include adaptation of the filter head to accommodate the Microsorban filter paper and the addition of a noise muffler to the blower.

[1] Mr. Collins is a staff member of the Health and Safety Laboratory, U.S. Atomic Energy Commission, New York City.

[2] Monthly gross beta averages and profiles of the 80th Meridian Network, Naval Research Laboratory, covering the period from November 1959 through December 1962, were reported monthly in *Radiological Health Data*, April 1960–April 1963. Results of the radiochemical analyses of the air filters for the calendar year 1960 and 1961 were presented in *RHD*, March 1962 and February 1963, respectively.

In all cases, samples were changed when possible on the 1st, 8th, 15th, and 22nd of the month and forwarded to HASL for gamma radiometric and radiochemical analysis. Each sample received was counted approximately two weeks after the midpoint of the sampling period on an 8 x 4 inch sodium iodide (thallium activated) crystal, obtaining both total gamma activity and the fraction of the gamma activity with energies above 1.0 Mev. The ratio of these two values serves as an age indicator (*1*). The results, in terms of gamma photons per minute per cubic meter, are listed in tables 1 and 2. The monthly averages are illustrated in figure 3 as an activity-latitude profile. Total beta activity estimates, obtained by the method described in the January 1963 report (*1*) are also listed in the tables.

Qualitative analysis of the gamma-ray spectra of these samples indicates that significant air con-

TABLE 1.—ACTIVITY OF SURFACE AIR, 80TH MERIDIAN NETWORK, MARCH 1963

Sampling station	Sampling period (dates—noon to noon)	Gamma activity (photons/min/m³)		Ratio $\left(\frac{\gamma > 1 \text{ Mev}}{\text{total } \gamma}\right)$	Estimated total beta activity
		Filter	Average for month		
Thule	8–15	8.01		0.017	5.4
	15–22	12.5		0.015	8.5
	22–4/1	12.2	10.9	0.017	8.2
Moosonee	1–8	7.28		0.015	4.9
	8–15	10.1		0.019	6.8
	15–22	7.35		0.014	5.0
	22–4/1	9.74	8.68	0.018	6.6
New York	1–8	11.2		0.025	7.6
	8–15	8.90		0.027	6.0
	15–22	8.38		0.021	5.7
	22–4/1	17.0	11.4	0.019	11.5
Washington	1–8	7.70		0.020	5.2
	8–15	7.08		0.021	4.8
	15–22	9.92		0.016	6.7
	22–4/1	14.9	10.4	0.017	10.1
Miami	1–8	9.77		0.020	6.6
	8–15	10.5		0.018	7.1
	15–22	9.15		0.016	6.2
	22–4/1	18.8	12.6	0.018	12.7
Mauna Loa	1–8	6.62		0.019	4.5
	8–15	11.5		0.018	7.8
	15–22	6.94		0.017	4.7
	22–4/1	6.11	7.63	0.018	4.1
San Juan	1–8	6.82		0.020	4.6
	8–15	8.49		0.018	5.7
	15–22	9.15		0.017	6.2
	22–4/1	7.92	8.09	0.018	5.4
Miraflores	1–8	6.87		0.021	4.6
	8–15	6.75		0.017	4.6
	15–22	9.17		0.016	6.2
	22–4/1	11.7	8.84	0.018	7.9
Guayaquil	*	—	—	—	—
Lima	—	—	—	—	—
Chacaltaya	15–22	0.249		0.034	0.17
Antofagasta	1–8	0.211		0.043	0.14
	8–15	0.214		0.025	0.14
	15–22	0.194		0.023	0.13
	22–4/1	0.221	0.210	0.018	0.15
Santiago	1–8	0.276		0.035	0.19
	8–15	0.0816		0.064	0.06
	15–22	0.264		0.039	0.18
	22–4/1	0.260	0.222	0.025	0.18
Puerto Montt	1–8	0.215		0.027	0.14
	8–15	0.317		0.025	0.21
	15–22	0.176		0.036	0.12
	22–4/1	0.279	0.260	0.052	0.19
Punta Arenas	1–8	0.136		0.029	0.09
	8–15	0.127		0.046	0.09
	15–22	0.126		0.015	0.08
	22–4/1	0.219	0.152	0.034	0.15

* Data not available.

TABLE 2.—ACTIVITY OF SURFACE AIR, 80TH MERIDIAN NETWORK, APRIL 1963

Sampling station	Sampling period (dates—noon to noon)	Gamma actiivty (photons/min/M³)		Ratio $\left(\frac{\gamma > 1 \text{ Mev}}{\text{total } \gamma}\right)$	Estimated total beta activity (pc/m³)
		Filter	Average for month		
Thule	1–8	8.65		0.018	5.8
	8–15	18.0		0.017	12.2
	15–22	14.1		0.018	9.5
	22–5/1	8.39	12.3	0.020	5.7
Moosonee	1–8	9.63		0.018	6.5
	8–15	7.91		0.018	5.4
	15–22	6.53		0.019	4.4
	22–5/1	5.29	7.35	0.023	3.6
New York	1–8	14.8		0.019	10.0
	8–15	18.1		0.021	12.2
	15–22	14.4		0.019	9.7
	22–5/1	15.2	15.6	0.019	10.3
Washington	1–8	15.9		0.020	10.8
	8–15	11.1		0.017	7.5
	15–22	19.9		0.019	13.5
	22–5/1	10.7	14.4	0.020	7.2
Miami	1–8	17.2		0.018	11.6
	8–15	16.0		0.019	10.8
	15–22	26.8		0.019	18.1
	22–5/1	15.6	18.9	0.020	10.5
Mauna Loa	1–8	12.0		0.018	8.1
	8–15	6.17		0.018	4.2
	15–22	8.86		0.020	6.0
	22–5/1	6.23	8.32	0.023	4.2
San Juan	1–8	6.59		0.019	4.4
	8–15	6.83		0.018	4.6
	15–22	22.5		0.020	15.2
	22–5/1	7.91	8.77	0.023	5.4
Miraflores	1–8	23.3		0.018	15.8
	8–15	3.03		0.018	2.0
	15–22	2.52		0.021	1.7
	22–5/1	4.00	8.21	0.022	2.7
Guayaquil	1–8	0.886		0.020	0.60
	8–15	0.817		0.019	0.55
	15–22	0.316		0.028	0.21
	22–5/1	0.253	0.568	0.024	0.17
Lima	1–8	0.287		0.033	0.19
	8–15	0.187		0.029	0.12
	15–22	0.200		0.030	0.14
	22–5/1	0.157	0.234	0.021	0.11
Chacaltaya	1–8	0.0551		0.081	0.04
	8–15	0.120	0.0876	0.030	0.08
Antofagasta	1–8	0.226		0.030	0.15
	8–15	0.184		0.029	0.12
	15–22	0.120		0.038	0.08
	22–5/1	0.164	0.174	0.025	0.11
Santiago	1–8	0.156		0.034	0.10
	8–15	0.176		0.041	0.12
	15–22	0.116		0.035	0.08
	22–5/1	0.262	0.176	0.021	0.18
Puerto Montt	1–8	0.140		0.039	0.10
	8–15	0.665		0.081	0.04
	15–22	0.813		0.036	0.46
	22–5/1	0.152	0.110	0.037	0.10
Punta Arenas	1–8	0.0481		0.089	0.32
	8–15	0.205		0.034	0.14
	15–22	0.0511		0.031	0.03
	22–5/1	0.0748	0.0948	0.070	0.05

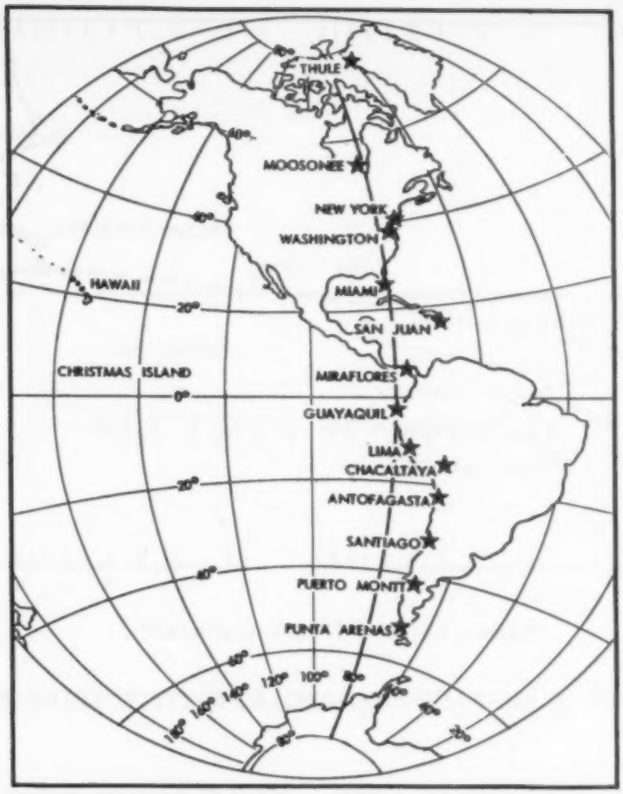

FIGURE 1.—ATMOSPHERIC RADIOACTIVITY SAMPLING STATIONS NEAR THE 80TH MERIDAIN (WEST)

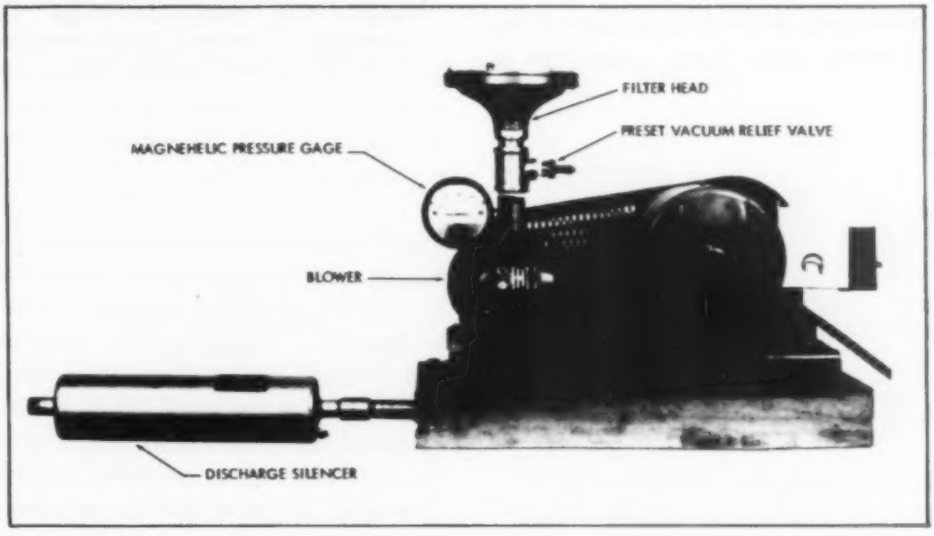

FIGURE 2.—NEW AIR SAMPLING EQUIPMENT FOR THE 80TH MERIDIAN NETWORK

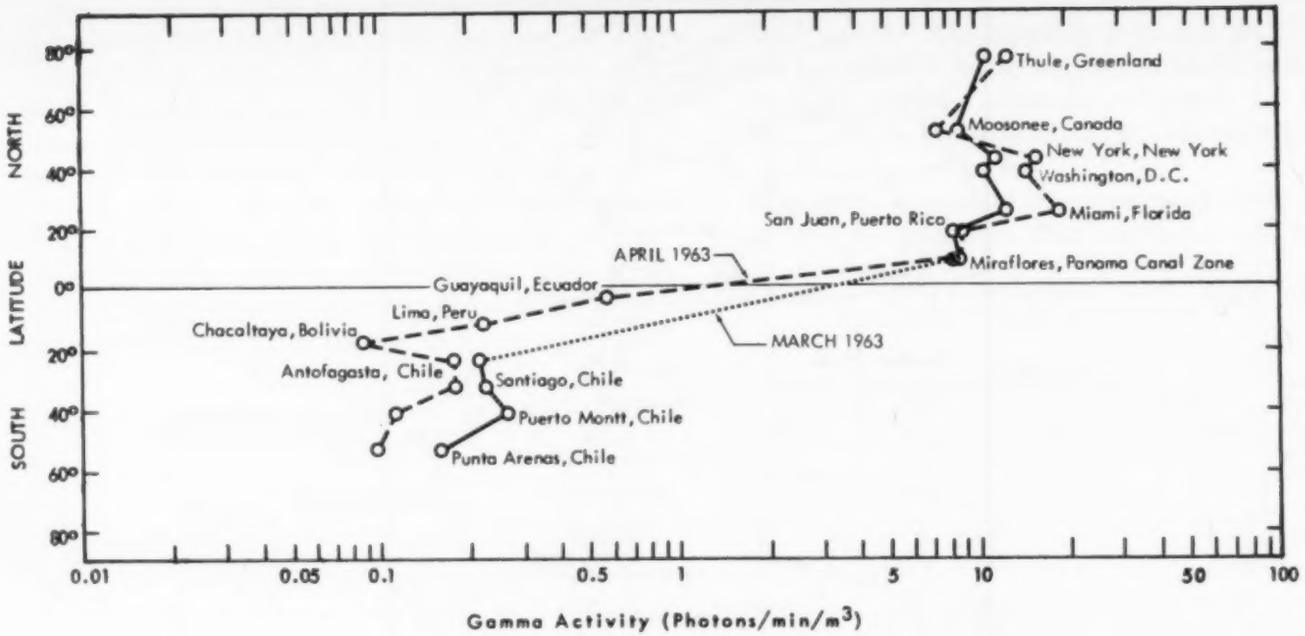

FIGURE 3.—PROFILE OF SURFACE AIR GAMMA ACTIVITY, MARCH AND APRIL 1963

centrations of antimony-124 (Sb^{124}) existed along the 80th meridian during March and April. This non-fission product contribution is not expected to affect the validity of the total gamma activity estimates, since the photon efficiency of the HASL counter for Sb^{124} has been found to agree with the average fission product photon efficiency adopted in the January report (0.35 gamma counts per photon). The total beta activity approximations are tentative, however, since large quantities of Sb^{124} distort the dating ratio and since the beta-to-gamma ratio for this nuclide is lower than that for mixed products.

REFERENCE

(*1*) Collins, W. R., Jr.: Fission Product Gamma Activity in Airborne Particulates, The 80th Meridian Network, January 1963, *Radiological Health Data*, 4:342–6, Superintendent of Documents, Government Printing Office, Washington 25, D.C. (July 1963).

SECTION II.—FOOD

Radionuclides in Institutional Diet Samples

January–March 1963

Division of Radiological Health, Public Health Service

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiation surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. This program is being administered by the Division of Radiological Health with the assistance of the Division of Environmental Engineering and Food Protection (*1*).

The program is designed to estimate the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program consisted of sampling diets in eight institutions, but it has since been expanded to 21 boarding schools or institutions, geographically distributed as shown in figure 1. Institutions selected range from financially well-to-do boarding schools to orphanages with severe economic limitations. Each institution (sampling point), except one, is located in a community from which the PHS Pasteurized Milk Network collects samples. The analytical data from this program supplement the findings for the Institutional Diet Sampling Program.

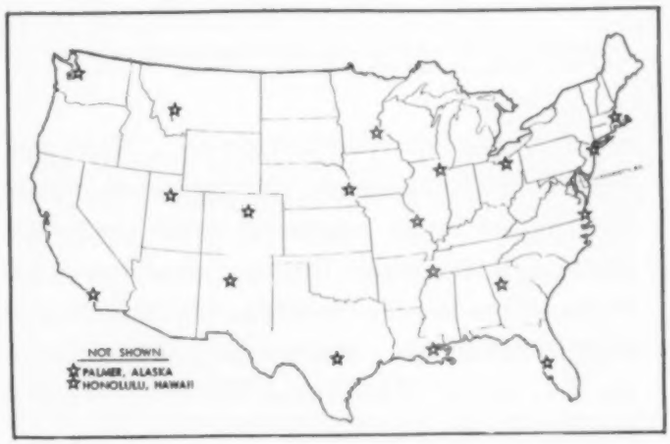

FIGURE 1.—INSTITUTIONAL DIET SAMPLING LOCATIONS, MARCH 1963

Sampling Procedure

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Each institution supplies one complete 7-day, 21-meal diet sample each month. Each day's sample is kept

TABLE 1.—INSTITUTIONAL DAILY DIETARY

Station	Month (1963)	Alaska, Palmer	California, Los Angeles	Colorado, Denver	Florida, Tampa	Georgia, Atlanta	Hawaii, Honolulu	Louisiana, New Orleans	Massachusetts, Boston	Minnesota, Minneapolis	Missouri, St. Louis	Montana, Helena
Age (years)		6–18	6–18	6–18	1–15	6–18	5–16	4–19	—	[a] <1–16	4–16	4–16
Total weight (kg/day)	Jan.	2.33	1.48	1.31	1.89	1.73	1.71	2.03	1.81	1.60		1.93
	Feb.	1.55	1.07	1.80	1.38	1.38	2.07	2.00	1.54	1.54		1.67
	Mar.	1.90	1.42	2.13	0.88	1.54	1.94	2.33	1.97	1.56	2.93	1.63
Calcium (g/day)	Jan.	1.7	0.7	0.6	1.2	0.9	0.5	1.4	1.2	0.6		0.8
	Feb.	0.7	0.5	1.4	1.0	0.9	0.9	1.5	1.3	0.6		1.1
	Mar.	1.3	0.7	1.4	0.6	0.8	0.2	1.6	1.6	0.7	2.2	1.3
Phosphorus as phosphate (g/day)	Jan.	5.4	3.2	2.6	4.3	4.0	2.6	4.7	5.8	2.6		3.1
	Feb.	3.6	1.9	3.2	3.7	3.2	3.9	4.9	4.1	2.6		4.0
	Mar.	4.5	3.1	4.9	0.7	1.1	3.3	2.1	3.8	3.0	7.3	4.2
Potassium (g/day)	Jan.	4.2	2.5	1.8	2.5	2.0	1.9	3.2	3.2	2.4		3.3
	Feb.	3.3		3.2	2.0	1.6	3.1	3.1	2.5	2.6		2.8
	Mar.	3.4	2.1	6.2	1.2	1.5	2.5	3.3	3.3	2.7	5.3	3.1
Total radium (pc/day)	Jan.	2.0	2.0	1.0	4.0	<2.0	8.0	6.3	<1.0	3.0		3.0
	Feb.	3.0	<1.0	<1.0	<2.0	<2.0	10.0	2.5	<1.0	<1.0		2.0
	Mar.	<1.0	1.0	1.0	2.9	5.2	2.0	4.7	<1.0	1.0	2.0	3.0
Strontium-89 (pc/day)	Jan.	30	<5	10	40	45	30	140	<5	5		5
	Feb.	30	<5	10	30	50	60	290	<5	15		25
	Mar.	60	8	45	30	60	65	350	<5	<5	20	30
Strontium-90 (pc/day)	Jan.	37	5	10	11	17	6	30	25	9		15
	Feb.	16	2	24	12	17	8	22	22	9		13
	Mar.	17	3	17	11	16	8	70	34	12	30	21
Cesium-137 (pc/day)	Jan.	255	35	90	125	50	35	110	170	80		85
	Feb.	155		110	90	55	85	140	125	85		100
	Mar.	145	35	155	70	60	155	210	180	105	115	80
Barium-140 (pc/day)	Jan.	<10	<10	<10	<20	<20	<10	<25	30	<10		<10
	Feb.	<10		<10	<15	<15	<10	<25	10	<10		<10
	Mar.	<10	<10	<10	<10	<20	<10	<30	<10	<10	<10	<10
Iodine-131 (pc/day)	Jan.	70	40	<10	<20	<20	<10	20	30	<10		<10
	Feb.	<10		<10	<15	<15	<10	30	<10	<10		<10
	Mar.	<10	20	<10	<10	<20	<10	<30	<10	40	<10	<10

[a] Food samples not collected from children too young for solid diet.
[b] Food samples collected from 5–14 year age group.

frozen during the collection period. After compositing the total sample, it is packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nevada, the Southeastern Radiological Health Laboratory, Montgomery, Alabama, or the Northeastern Radiological Health Laboratory, Winchester, Massachusetts.

Each sample was packaged in three containers: one containing solid food minus seeds, pits, rinds, shells and bones that would not ordinarily be eaten; one containing dairy products such as milk, cottage cheese, and ice cream; and one containing soft drinks, coffee, tea, and water. A record of the contents of each meal and the approximate weight of each item was made by the institution's dietician and sent with the sample. Samples usually range from 6 to 16 liters in volume and weigh from 8 to 20 kilograms.

Analytical Procedures

Because calcium and phosphorus compounds may have an effect on the uptake of important boneseeking radionuclides such as strontium–89 and strontium–90 (*2*), they are included in the analytical program. Total weight, stable calcium, and stable potassium determinations are obtained by conventional, gravimetric or spectrophotometric methods. Phosphate determinations are made by a colorimetric technique.

The radioanalysis program is designed around three basic procedures: (1) gamma spectroscopy (2) chemical separation of strontium–89 and strontium–90 with subsequent counting, and (3) total radium analysis. In the absence of interferences other than that from naturally-occurring radioactive potassium (K^{40}), minimum detectable concentrations for the gamma scan on a per-kilogram basis are: iodine–131, 10 pc/kg; cesium–137, 5

INTAKE (BASED ON A 7-DAY COMPOSITE SAMPLE)

Station	Month (1963)	Nebraska, Omaha	New Mexico, Albuquerque	New York, New York	Ohio, Cleveland	Tennessee, Memphis	Texas, Austin	Utah, Salt Lake City	Virginia, Norfolk	Washington, Seattle	Monthly Minimum Average	Monthly Maximum Average
Age (years)		6–18	[b] <1–14	8–15	6–15	8–18	6–18	12–18	10–18	6–16	—	—
Total Weight (kg/day)	Jan.	1.77	1.86	1.66	1.89	1.09	2.20	1.36	1.06	2.85	1.77	1.77
	Feb.				1.92	1.37	2.25	1.72	1.34	3.08	1.72	1.72
	Mar.	1.70	1.80		1.92	1.33	2.35	1.56	1.05	2.71	1.82	1.82
Calcium (g/day)	Jan.	1.3	1.4	1.9	1.4	0.5	1.4	0.6	0.6	2.1	1.1	1.1
	Feb.				2.0	1.2	1.4	1.3	0.6	2.2	1.2	1.2
	Mar.	1.2	1.6		1.4	1.0	1.2	1.1	0.5	2.2	1.2	1.2
Phosphorus as phosphate (g/day)	Jan.	4.3	4.7	4.6	7.1	1.9	5.6	2.7	2.6	7.4	4.1	4.1
	Feb.				5.7	3.9	5.7	4.7	3.2	7.5	4.1	4.1
	Mar.	3.9	5.2		3.9	1.1	1.9	3.7	0.9	7.9	3.5	3.5
Potassium (g/day)	Jan.	3.6	3.8	3.3	4.0	2.1	3.6	2.6	1.6	4.8	3.0	3.0
	Feb.				3.0	2.5	3.1	3.1	2.2	3.6	2.8	2.8
	Mar.	2.9	2.5		3.4	2.3	2.9	2.8	1.4	3.1	2.9	2.9
Total radium (pc/day)	Jan.	1.0	1.0	<1.0	<1.0	<2.0	<3.0	2.0	<2.0	6.0	2.2	2.8
	Feb.				<1.0	<2.0	<3.0	1.0	<2.0	12.0	1.8	2.8
	Mar.	<1.0	4.0		<1.0	2.3	3.7	<1.0	1.0	1.0	1.8	2.1
Strontium-89 (pc/day)	Jan.	20	20	<5	<5	45	120	5	20	80	34	35
	Feb.				<5	60	70	5	70	60	46	47
	Mar.	35	25		<5	85	85	40	40	115	58	58
Strontium-90 (pc/day)	Jan.	21	9	25	18	7	20	9	13	25	16	16
	Feb.				25	17	23	15	12	36	18	18
	Mar.	7	5		39	17	22	8	12	29	20	20
Cesium-137 (pc/day)	Jan.	105	<5	85	130	45	110	75	35	200	96	97
	Feb.				105	55	55	170	45	230	106	106
	Mar.	70	35		80	65	70	125	35	190	104	104
Barium-140 (pc/day)	Jan.	70	<10	<10	<10	<15	<25	<10	<15	<10	6	18
	Feb.				20	<15	<25	<10	<15	150	11	23
	Mar.	<10	<10		<10	<20	<30	80	<10	<10	4	17
Iodine-131 (pc/day)	Jan.	<10	<10	<10	30	<15	<25	<10	<15	60	14	23
	Feb.				<10	<15	<25	<10	<15	<10	2	14
	Mar.	<10	<10		<10	<20	<30	<10	<10	<10	3	15

pc/kg; and barium–140, 10 pc/kg. Approximate minimum detectable concentrations for strontium–89, strontium–90, and total radium are: 5, 1, and 1 pc/kg, respectively.

Total radium is determined by ashing, separation, and coprecipitation of radium as sulfate or chromate. After samples are transferred to planchets and dried, alpha activity is measured by an internal proportional counter with an appropriate delay for checking ingrowth of radium daughters. Since naturally-occurring radionuclides may contribute to the reported total radium values, the total radium technique is a practical screening indicator only. The bone dose, calculated by assuming total radium to be only radium–226, would therefore be moderately high.

Data

Table 1 presents the dietary intake data expressed on a per-day basis from January 1963 through March 1963 for the 20 institutions from which samples were received. Also contained in the table is the range of ages of children at each institution. The reported iodine–131 values are based on the iodine–131 content of the sample at the end of the sample collection period. Therefore, the true iodine–131 intakes may be somewhat greater than the reported values.

Certain of the radioanalyses are reported by the laboratories as being "less than" (<) a specified value. For data averaging, the method employed for presentation in table 1 is that all "less-than" data are assumed to be equal to the full "less-than" values as they appear in the column entitled "monthly maximum averages." The column entitled "monthly minimum averages" reflects the averages in which all "less than" values are considered to be zero.

Strontium–89, strontium–90, iodine–131, cesium–137, and barium–140 averages of the daily intakes at the institutions, as well as announced atmospheric nuclear detonations for 1961 through 1963, are shown in figure 2.

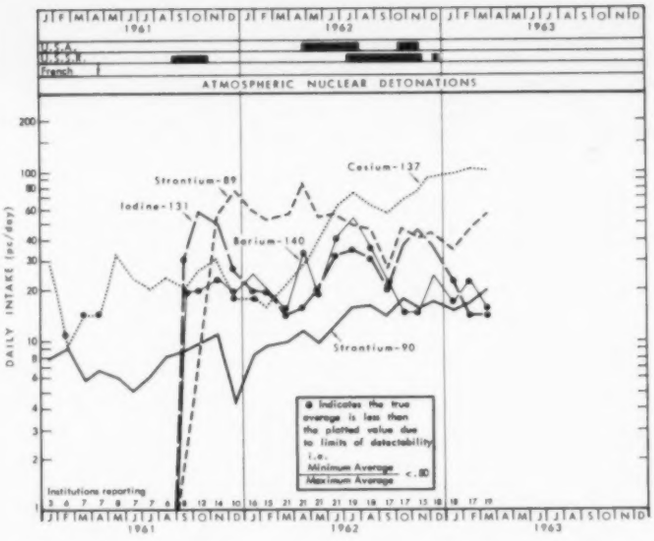

FIGURE 2.—RADIONUCLIDES IN INSTITUTIONAL DIET SAMPLES—AVERAGE OF INSTITUTIONS

For convenience the data are presented graphically in figures 3–10 as station distributions versus daily intake. These are not graphs of continuous functions as might be inferred from their appearance. For example, in figure 3, total dietary intake of food is divided into six ranges (<1.00, 1.00–1.49, 1.50–1.99, 2.00–2.49, 2.50–2.99, and 3.00–3.50 kg/day), and the number of institutions in each range is noted and plotted as a bar graph. The maximum of each bar is connected by a smooth curve. This type of construction is used for each month for each item represented in figures 3–10. The number of stations used in constructing these graphs was 18, 17, and 19 for the months of January, February and March 1963, respectively. A variation of two institutions is probably not significant in considering trends in the data.

Discussion of Data

During the 3-month period reported, the dietary intake of strontium–90 ranged between 2 and 70 pc/day, with 35 of 54 institution-months* being, for purposes of comparison, in the lowest Federal Radiation Council (FRC) Range of intake. This lowest Range established for strontium–90 by the FRC is 0 to 20 pc/day averaged over the period of one year (*3*, *4*).

The strontium–89 distribution (figure 8) shows that the majority of institution-month values are below 40 pc/day. The FRC Range I for strontium–89 is 0 to 200 pc/day (*3*). Only the New Orleans station samples had values in FRC Range II, which is 200 to 2,000 pc/day.

The dietary intake of total radium ranged between <1.0 and 12.0 pc/day with 94 percent of the institution-months being 6.0 pc/day or less. Assuming the radium–226 component to be one-third of the total radium activity (*3*), the intake of radium–226 via the diet probably approaches the top of FRC Range I (0 to 2 pc/day for radium–226) at a few institutions.

Following the resumption of nuclear weapons testing in the atmosphere in 1961, iodine–131 dietary intake increased from nondetectable levels to an institutional high of 390 pc/day. During the period of January–March 1963, the institutional high was 70 pc/day. FRC Range II for iodine–131 is 10–100 pc/day (*3*). Barium–140 was generally not detectable during this period, although the maximum intake of 150 pc/day was observed at Seattle in February.

The cesium–137 dietary intake ranged from <5 to 255 pc/day during the period reported, with 28 of 53 reported values being less than 100 pc/day.

The distributions of total intake of food by weight for this quarter (figure 3) are similar to those for the previous period. The total weight of food consumed ranged between 0.88 and 3.03 kg/day, with 40 of 54 institution months being between 1 and 2 kg/day.

* An institution-month is one datum value per institution per month. (e.g., 20 institutions reporting one value per month for 3 months is 60 institution-months).

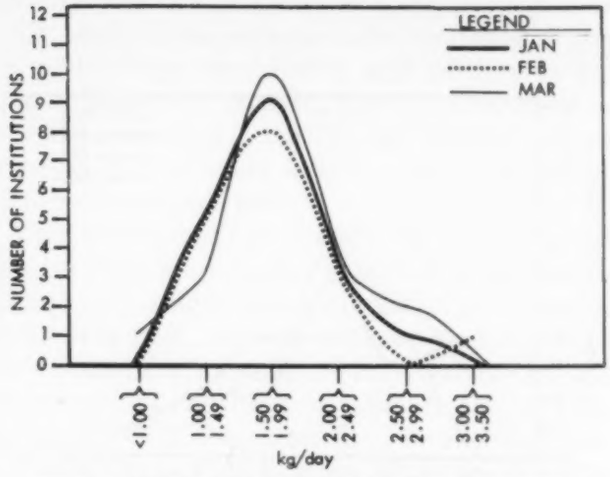

FIGURE 3.-- DISTRIBUTIONS OF INSTITUTIONS VERSUS TOTAL DAILY DIETARY INTAKE ON A WEIGHT BASIS

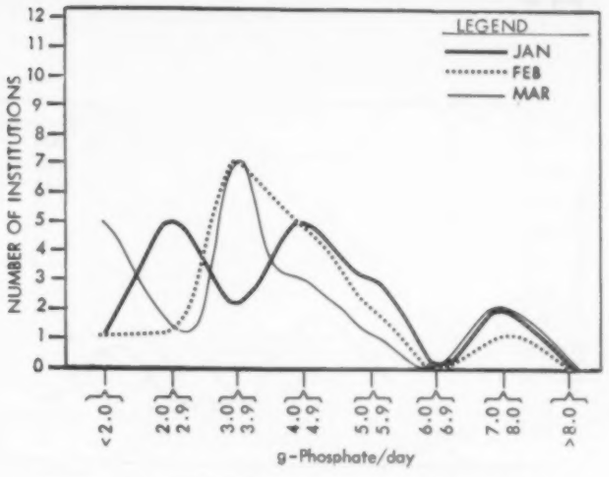

FIGURE 6.-- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY PHOSPHATE INTAKE

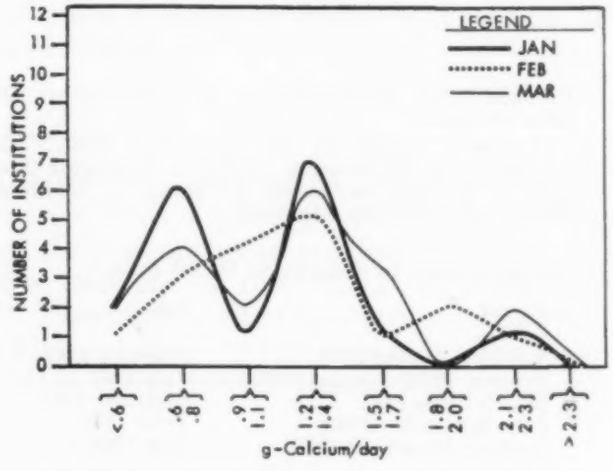

FIGURE 4.-- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY CALCIUM INTAKE

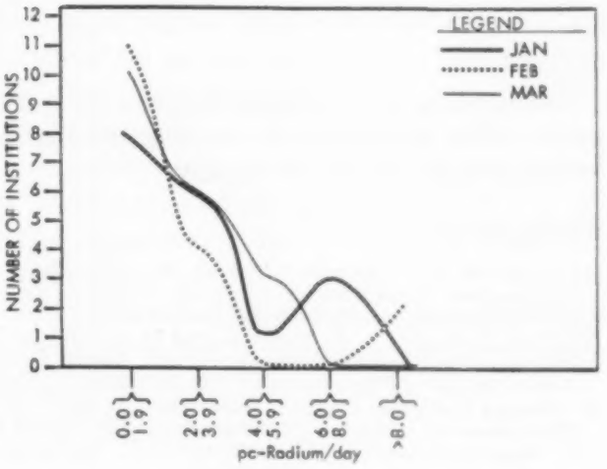

FIGURE 7 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY TOTAL RADIUM INTAKE

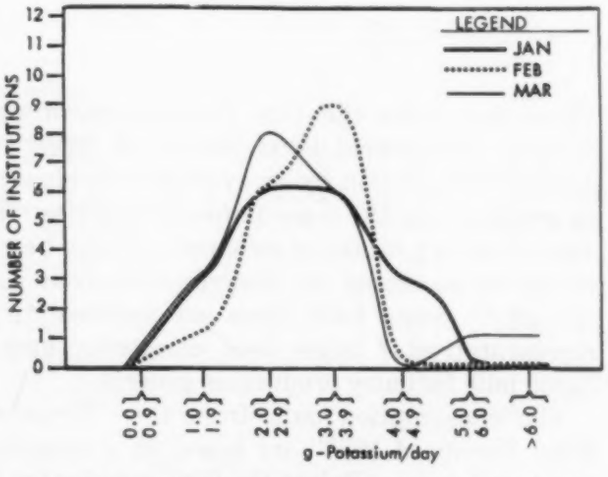

FIGURE 5 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY POTASSIUM INTAKE

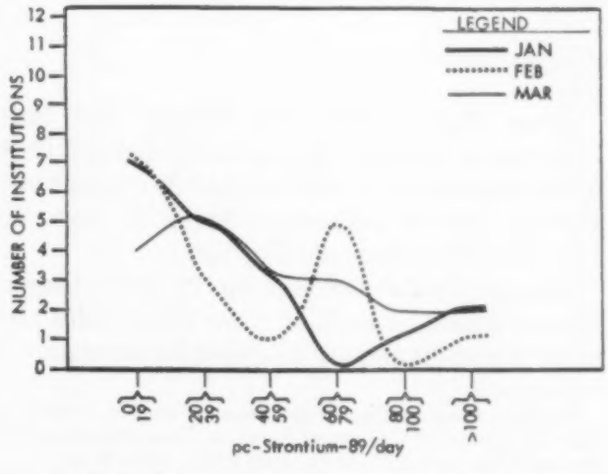

FIGURE 8-- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY STRONTIUM-89 INTAKE

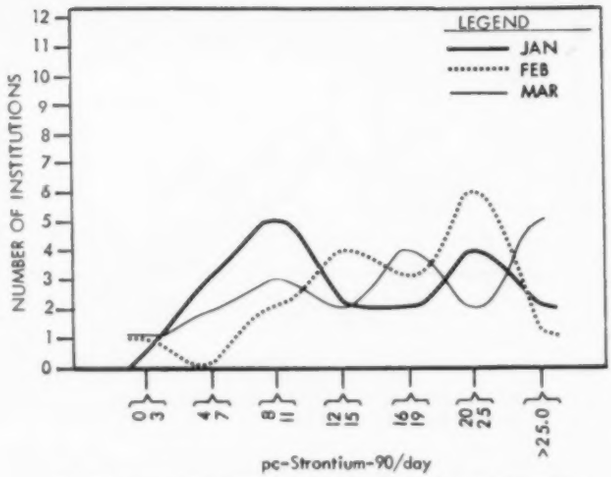

FIGURE 9.-- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY STRONTIUM-90 INTAKE

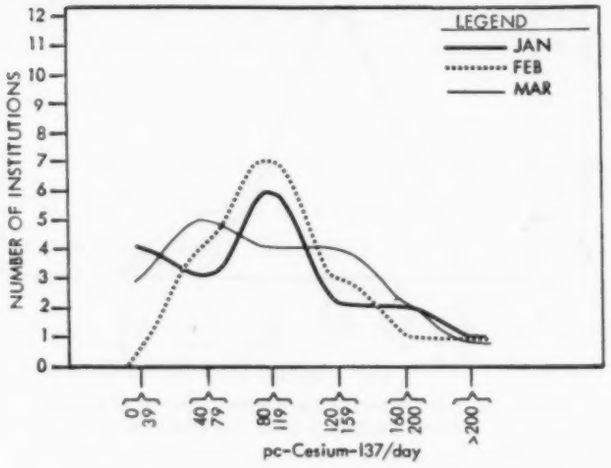

FIGURE 10.-- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY CESIUM-137 INTAKE

The calcium intake ranged between 0.2 and 2.2 g/day while 67 percent of the institution-month values were greater than 0.8 g/day.

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Previous coverage in *Radiological Health Data:*

Period	Issue
January–August 1961	*February 1962*
January 1961–February 1962	*July 1962*
March–June 1962	*December 1962*
July–September 1962	*April 1963*
October–December 1963	*July 1963*

Tri-City Diet Study[1]

November 1962–January 1963

Joseph Rivera[2]

Since March 1960, the Health and Safety Laboratory through its quarterly diet study, has made estimates of the strontium–90 content of the average diet of individuals living in New York City, San Francisco, and Chicago.

Selected foods representing 19 food categories are purchased at each of these three cities about every 3 months and are analyzed for strontium–90. Using data from the U.S. Department of Agriculture, "Household Food Survey of 1955," the annual consumption by an average individual can be grouped into the same 19 food categories. The annual dietary intake of strontium–90 can be estimated by summing the contributions from each category. Some food types are assumed to be representative of larger food categories, such as liquid milk for dairy products in general.

The consumption data from the "Household Food Survey of 1955" are based on a weight-as-purchased basis. Before the food samples for the Tri-City Diet Study are ashed for radiochemical

[1] *Fallout Program Quarterly Summary Report, HASL–138*, 163–165, Office of Technical Services, Department of Commerce, Washington 25, D.C. (July 1963), price $3.50.

[2] Mr. Rivera is a physicist on the staff of the Environmental Studies Division, Health and Safety Laboratory, U.S. Atomic Energy Commission.

analysis, they are prepared to a certain degree as if for actual consumption. For example, fruits are peeled, eggs are shelled, and poultry is deboned. Therefore, concentrations of radioactivity in foods as reported in the Tri-City Diet Study are based on the trimmed weight. No correction is made for the wasted food.

After two samplings at each city it was found that the calcium content of most food categories did not vary among cities, nor did it vary significantly with time. Calcium analyses were therefore discontinued and average calcium content of foods was computed and used to estimate the average annual intake of this mineral. The specific numbers used to calculate calcium intake are given in HASL–113 (*1*).

Results obtained from the eleventh sampling of foods (November 1962–January 1963) are presented in table 1. The variation with time of the daily intake of strontium–90 in the three cities is plotted in figure 1.

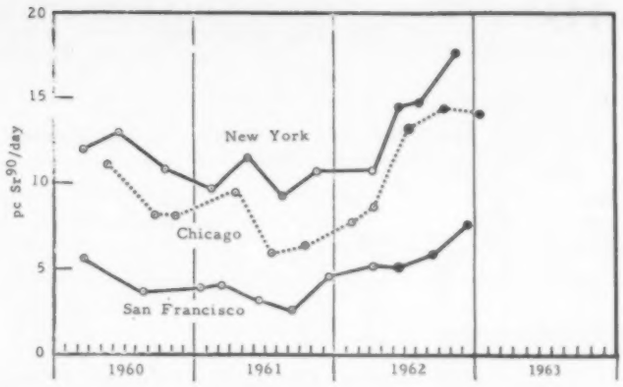

FIGURE 1.—DAILY INTAKE OF STRONTIUM–90 IN TRI-CITY TOTAL DIETS

Discussion

The trend of increasing daily intake of strontium–90 at each of the three cities, which started after the resumption of atmospheric testing of nuclear weapons by the U.S.S.R. in September 1961, is seen in figure 1 to have continued through the winter of 1962. The average daily strontium–90 intake during 1960, 1961, and 1962 at each of the cities is shown in table 2. Of the three cities, New York City has always had the highest levels and San Francisco the lowest. The average daily intake of strontium–90 at New York City in 1962 was about 4.0 pc/day greater than that in 1961. If a similar increase occurred in 1963, the average daily intake of strontium–90 in 1963 at New York City would be about 19 pc/day, which is near the top of Range I (0–20 pc/day) of the intake guidance established by the Federal Radiation Council (*2*).

Partly due to its high annual consumption, milk continues to be the predominant source of strontium–90 in the diet.

TABLE 1.—AVERAGE PER PERSON DIETARY CONSUMPTION AND STRONTIUM–90 INTAKE—ELEVENTH SAMPLING

Food Category	Average U. S. consumption		New York City November 1962		Chicago January 1963		San Francisco December 1962	
	Diet kg/yr	Calcium (g/yr)	pc/kg	pc/yr	pc/kg	pc/yr	pc/kg	pc/yr
Bakery products	37	37.0	[a]18.7 ± 1.4	692	[a]16.8 ± 1.2	622	[a]9.7 ± 0.8	359
Whole grain products	11	10.0	35.8 ± 1.6	394	41.5 ± 1.8	457	21.5 ± 1.1	237
Eggs	16	9.1	1.2 ± 0.1	19	3.2 ± 0.1	51	1.7 ± 0.1	27
Fresh vegetables	43	15.0	16.8 ± 0.6	722	7.4 ± 0.4	318	3.8 ± 0.4	163
Root vegetables	17	6.1	15.7 ± 0.6	267	6.5 ± 0.3	111	5.5 ± 0.3	94
Milk	221	234.3	10.0 ± 0.5	2210	9.5 ± 0.5	2100	5.0 ± 0.4	1105
Poultry	17	9.2	1.2 ± 0.1	20	1.1 ± 0.1	19	1.1 ± 0.1	19
Fresh fish	8	10.8	0.5 ± 0.1	4	0.9 ± 0.1	7	0.3 ± 0.1	2
Flour	43	8.6	17.2 ± 0.4	740	12.7 ± 0.4	546	4.2 ± 0.3	181
Macaroni	3	0.7	9.3 ± 0.4	28	14.5 ± 0.6	44	8.3 ± 0.4	25
Rice	3	1.1	1.9 ± 0.3	6	2.4 ± 0.3	7	1.9 ± 0.2	6
Meat	73	10.9	2.3 ± 0.2	168	1.0 ± 0.1	73	0.8 ± 0.1	58
Shellfish	1	0.8	5.0 ± 0.5	5	0.7 ± 0.1	1	1.3 ± 0.1	1
Dried beans	3	2.9	12.0 ± 1.3	36	17.3 ± 1.5	52	11.0 ± 1.6	33
Fresh fruit	68	13.6	9.1 ± 0.4	619	2.0 ± 0.2	136	1.9 ± 0.3	129
Potatoes	45	5.8	3.0 ± 0.4	135	9.1 ± 0.5	410	1.5 ± 0.4	68
Canned fruit	26	1.3	1.8 ± 0.2	47	1.7 ± 0.2	44	0.7 ± 0.1	18
Fruit juices	19	1.7	3.2 ± 0.3	61	2.9 ± 0.3	55	2.2 ± 0.3	42
Canned vegetables	20	4.2	10.2 ± 0.8	204	5.7 ± 0.5	114	1.2 ± 0.4	24
Annual intake	674	383		6377		5167		2591
pc Sr^{90}/g Ca in total diet				16.7		13.5		6.8

[a] Error terms are one standard deviation (due to counting).

TABLE 2.—ANNUAL AVERAGE DAILY STRONTIUM-90 INTAKE, 1960–1962

[pc/day]

Date	New York City	Chicago	San Francisco
1960	12.0	9.2	4.3
1961	10.2	7.4	3.5
1962	14.4	12.6	5.8

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(1) U.S. Atomic Energy Commission: *Fallout Program Quarterly Summary Report, HASL-113*, Office of Technical Services, Department of Commerce, Washington 25, D.C. (July 1, 1961), price $2.50.

(2) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2*, Superintendent of Documents, Government Printing Office, Washington 25, D.C. (September 1961), price 20¢.

Recent coverage in *Radiological Health Data:*

Period	*Issue*
Sixth sampling (August–October 1961)	*June 1963*
Seventh sampling (November 1961–February 1962	*September 1962*
Eighth sampling (April 1962)	*January 1963*
Ninth sampling (June–July 1962)	*March 1963*
Tenth sampling (August–September 1962)	*June 1963*

Temporal and Geographical Distributions of Strontium-90 and Cesium-137 in Food

1960–1962

Edwin P. Laug [1]

Since 1960, the Food and Drug Administration (FDA) has been collecting and analyzing individual foods in order to determine their content of strontium–90 and cesium–137 resulting from fallout. This report summarizes and interprets all data amassed during the surveillance period of 1960, 1961, and 1962. No 1963 data are included. Except where noted, all products were raw and unprocessed. About 3200 individual samples were analyzed for strontium–90 content and 400 samples were analyzed for cesium–137. The sampling base for this survey was quite broad, including 92 different varieties of domestic and imported foods. Included in this summary are results from a survey of 24 varieties of baby food. Experiments were conducted concurrently to determine the effect of processing operations, such as peeling, washing, canning, freezing, and milling on the amount and distribution of fallout contamination.

Sampling Methodology

Individual foods were sampled on as broad a basis as possible with respect to variety. Because of different growing times and areas, however, a regular schedule or fixed geographical grid could not be systematized, as is the case with the milk, water and air radioactivity monitoring networks operated by the Public Health Service. Samples were drawn at harvest from all major growing areas in the continental U.S. (see figure 1) and repeated samplings were made throughout the period covered by this resume. Products sampled, sampling frequency, and priorities assigned were reviewed at intervals as surveillance findings became available. Occasionally, decisions to modify existing schedules were made when the air sampling network of the Public Health Service indicated localized fallout situations. Most foods collected were raw agricultural products, which were usually unwashed and unpeeled, and generally in the condition in which they would be found in a warehouse or store. Most imports (tea bales, spice bales, coffee beans, cocoa beans) were also raw and unprocessed. When processed samples were collected, an attempt was made to identify the raw lot from which the finished product was manufactured.

All samples were collected by FDA inspectors, either directly from the individual grower or from the storage sheds where crops were assembled before shipment. Import samples were usually collected at dockside. Collection records kept by the inspector included date of collection, date of harvest, date of planting, name of grower or growers, location of farm by county and State or foreign country, and name and location of marketing cooperative or dealer. Manufactured items

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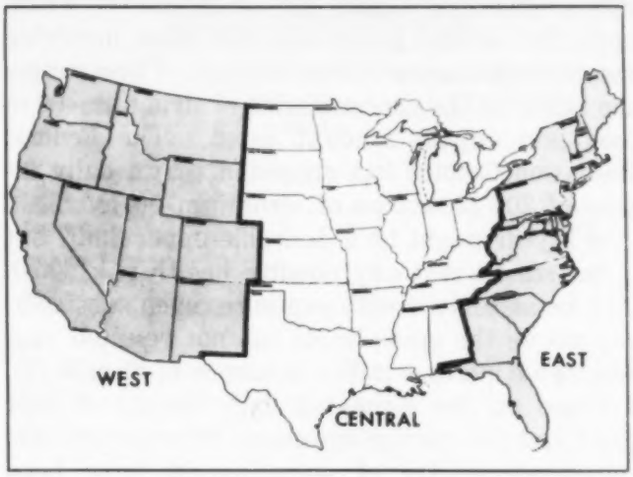

FIGURE 1.—HARVEST REGIONS

such as baby foods or flour were identified by dealer and/or manufacturer and also by source of the raw material.

Radiochemical Methodology

Analyses for strontium–90 were essentially as outlined in the HASL Manual of Standard Procedures (*1*). Samples were prepared and analyzed for cesium–137 as described in an earlier report (*2*).

RESULTS

Strontium–90 Content of Individual Foods and Food Groups

Table 1 gives the content of strontium–90 by food groups arranged in descending order of concentration. Individual foods which make up the groups are listed in tables 2 through 12. Tea and spices appear to carry the highest levels of contamination in human food, while sea foods, eggs and white potatoes seem to contribute the least strontium–90 to the food chain. Baby foods generally reflect the strontium–90 levels found in the corresponding foods eaten by adults. Considering the association of strontium with calcium, the high levels in bone are not surprising. Poultry bones, however, contain less strontium–90 than other bones—a fact that may be explained by the relatively large accretion of strontium–90 in egg shells. Worthy of comment are Brazil nuts, which contain about five times as much strontium–90 as the other nuts. It is known that Brazil nuts translocate radium from the soil (*3*), and as strontium belongs to the same periodic grouping of elements (Group II), we may assume that the

TABLE 1.—STRONTIUM–90 CONTENT OF HUMAN FOODS PRODUCED AND HARVESTED IN 1960–1962

Type of food	No. of varieties	No. of samples	Picocuries strontium-90 per kilogram	
			Average	Range
Raw agricultural products				
Tea[1]	1	159	390	19–1,720
Spices	10	61	165	1.9–2,590
Brazil nuts	1	9	63	18–119
Dairy products[2]	2	84	43	2.1–140
Leafy vegetables[3]	6	335	30	0.5–299
Grains[4]	4	279	29	0.5–447
Legumes[5]	4	234	16	0.0–272
Berries[6]	4	86	16	0.9–110
Coffee[1]	1	130	16	0.9–48
Cocoa beans	1	33	14	1.3–25
Brassicae[7]	4	180	12	0.2–100
Nuts[8]	5	78	12	0.0–81
Root vegetables[9]	6	293	11	0.1–118
Miscellaneous vegetables[10]	2	34	6.2	0.2–38
Fruits[11]	20	485	4.0	0.0–46
Rice	1	11	3.7	0.2–8.3
White potatoes	1	134	2.4	0.0–12
Egg substance[12]	1	27	1.8	0.3–3.8
Corn	1	55	1.5	0.0–8.8
Sea food[13]	10	222	0.9	0.0–9.8
Processed baby foods				
Cereal products	6	40	11	0.1–49
Strained vegetables	7	33	7.0	0.8–25
Strained fruits	6	29	0.9	0.0–3.9
Strained meats	5	13	0.9	0.1–2.7
Organic calcium sources				
Fresh bone[14]	4	4	595	431–873
Bone flour	—	13	550	75–2,100
Egg shells	1	21	407	39–1,300
Fresh poultry bone[15]	2	12	81	11–190

[1] Leaves or beans respectively, not the beverage.
[2] Cheese and evaporated milk.
[3] Lettuce, spinach, parsley, collards, kale, celery.
[4] Wheat, oats, barley, rye.
[5] Lima beans, snap beans, soybeans, peas.
[6] Strawberries, blueberries, blackberries, cranberries.
[7] Cabbage, Brussels sprouts, cauliflower, broccoli.
[8] Pecans, cashews, walnuts, almonds, peanuts.
[9] Carrots, beets, turnips, radishes, onions, sweet potatoes.
[10] Artichokes, asparagus.
[11] With exception of berries.
[12] Without shell.
[13] Shellfish, crustacea, oceanic fish.
[14] Beef, pork, veal, poultry waste discards from FDA Teen-Ager Diet Study, 1961–1962, Washington, D.C.
[15] Chicken and turkey.

TABLE 2.—STRONTIUM–90 CONTENT OF VEGETABLES HARVESTED IN 1960–1962

Variety	No. of samples	Picocuries of strontium-90 per kilogram	
		Average	Range
Leafy			
Kale	3	132	22 –237
Collards	14	123	29 –299
Parsley	28	86	21 –178
Spinach	60	41	2.7–264
Lettuce	125	16	0.5–178
Celery	105	11	0.7– 60
Legumes			
Soybeans	32	42	10 –272
Snap beans	102	18	0.3– 98
Peas	62	8.0	0.0– 53
Lima beans	38	5.6	0.4– 28
Brassicae			
Broccoli	17	23	0.2–100
Cabbage	133	12	0.3– 68
Brussels sprouts	7	4.9	0.2– 8.1
Cauliflower	23	3.7	0.6– 10
Miscellaneous			
Artichoke	8	17	3.9– 38
Asparagus	26	2.5	0.2– 12

plant displays a similar propensity to concentrate this nuclide. Grains such as wheat, oats, rye and barley rank relatively high in the order of strontium–90 content, while rice and corn rank at the lower end of the order. In the case of corn, it appears obvious that the husk effects nearly complete protection from surface contamination. A striking difference between sweet potatoes and white potatoes is evident; the former contains about ten times as much strontium–90 (table 3). Among the fruits (table 4) the berries are seen to carry significantly higher levels of strontium–90 than some of the smooth skinned fruits such as apples and tomatoes. The latter, in fact, contain some of the lowest levels of strontium–90 observed in this survey.

Because of the universality of fallout contamination in food, an orientation as to the significance of findings listed in table 1 is very desirable. The Federal Radiation Council has established a set of intake guidance ranges for strontium–90 which apply for normal peacetime operations involving the controlled use of atomic energy. These ranges are based on the concentration of strontium–90 in food and on the amount eaten. The Federal Radiation Council has suggested that a daily intake of 200 picocuries of strontium–90 averaged over a year might be a desirable upper limit, but it has stated that any possible health risk which may be associated with exposures even substantially above the guide levels has not resulted in a detectable increase in the incidence of disease (4).

Based on the estimated daily weight of food eaten and the average strontium–90 concentration, calculated intakes of strontium–90 have been listed in table 12 in descending order. It can be seen that, of 5 major food groups surveyed, dairy products head the order. Tea and spices, which have a relatively high content of strontium–90, rank well down in the order, and contribute less than 1 pc per day, on the average, to the diet.

In order to estimate the potential strontium–90 intake under the worst situation, calculations of intake were also derived from the highest strontium–90 concentration recorded for any particular food item. Based on values in table 12, the potential daily intake from ingestion of a number of food groups is as follows: grain products, 100 pc; dairy products, 59 pc; root vegetables, 42 pc; vegetables, 55 pc; fruits, 37 pc. For individual foods: lettuce, 5.9 pc; snap beans, 2.3 pc; onions, 2.1 pc. Thus, it is seen that only in exceptional cases occurring at

TABLE 3.—STRONTIUM–90 CONTENT OF ROOT VEGETABLES HARVESTED IN 1960–1962

Variety	No. of samples	Picocuries of strontium–90 per kilogram	
		Average	Range
Sweet potatoes	32	22	2.3–118
Turnips	29	16	0.5– 65
Beets	48	15	0.7–104
Radishes	29	9.8	0.6– 92
Onions	80	7.5	0.1– 76
Carrots	75	4.9	0.5– 25
Potatoes	134	2.4	0.0– 12

TABLE 4.—STRONTIUM–90 CONTENT OF FRUITS HARVESTED IN 1960–1962

Variety	No. of samples	Picocuries of strontium–90 per kilogram	
		Average	Range
Cranberries	10	34	3.4–110
Strawberries	60	15	0.9– 59
Blueberries	12	12	5.7– 33
Blackberries	4	12	2.7– 22
Oranges	9	11	1.5– 27
Grapefruit	7	5.1	0.4– 16
Squash	47	7.7	0.4– 12
Pumpkin	24	6.1	0.5– 26
Cucumber	24	5.3	0.5– 17
Cantaloupe	8	3.8	0.1– 24
Olives	7	13	2.3– 46
Figs	17	7.5	2.1– 9.5
Cherries	48	6.1	0.9– 16
Grapes	15	5.4	0.4– 16
Raisins	8	3.5	0.0– 8.8
Peaches	68	3.3	0.4– 12
Pears	9	2.6	0.1– 14
Dates	7	2.3	0.6– 8.7
Avocado	6	1.5	0.1– 4.7
Apples	58	1.1	0.1– 7.0
Bananas	7	0.2	0.1– 0.5
Egg Plants	2	5.4	4.3– 6.5
Peppers	27	2.6	0.0– 11
Tomatoes	104	1.9	0.1– 11

TABLE 5.—STRONTIUM–90 CONTENT OF GRAINS HARVESTED IN 1959–1962

Variety	No. of samples	Picocuries of strontium–90 per kilogram	
		Average	Range
Oats	43	43	2.0–447
Rye	26	40	6.5–265
Wheat	168	25	0.9–241
Barley	42	21	0.5– 90
Rice	11	3.7	0.2– 8.3
Corn	55	1.5	0.0– 8.8

TABLE 6.—STRONTIUM–90 CONTENT OF COFFEE, TEA, AND COCOA BEANS IMPORTED IN 1960–1962

Product	No. of samples	Picocuries of strontium–90 per kilogram	
		Average	Range
Tea	159	390	19 –1,720
Coffee	130	16	0.9– 48
Cocoa beans	33	14	7.3– 25

TABLE 7.—STRONTIUM-90 CONTENT OF SEA FOOD COLLECTED IN 1960–1962

Variety	No. of samples	Picocuries of strontium-90 per kilogram	
		Average	Range
Shellfish			
Oysters	26	1.1	0.0–9.8
Clams	21	0.7	0.0–4.6
Crustacea			
Crab	8	2.8	0.0–5.8
Shrimp	29	1.0	0.0–3.3
Lobster	12	0.6	0.0–1.5
Fish			
Sardine	36	1.6	0.0–8.1
Haddock	10	0.6	0.1–2.1
Salmon	6	0.6	0.0–1.4
Tuna	60	0.3	0.0–1.7
Bonita	14	0.3	0.0–1.0

TABLE 8.—STRONTIUM-90 CONTENT OF DAIRY PRODUCTS AND EGGS PRODUCED IN 1960–1962

Variety	No. of samples	Picocuries of strontium-90 per kilogram	
		Average	Range
Egg shell	21	407	39 –1,300
Cheese	59	50	11 – 140
Evaporated milk	25	26	2.1– 64
Egg substance	27	1.8	0.3– 3.8

TABLE 9.—STRONTIUM-90 CONTENT OF SHELLED NUTS HARVESTED IN 1961 AND 1962

Variety	No. of samples	Picocuries of strontium-90 per kilogram	
		Average	Range
Brazil nuts	9	63	18 –119
Peanuts	22	37	6.8– 81
Pecans	21	15	3.2– 50
Almonds	8	7.6	0.7– 19
Walnuts	11	2.5	0.0– 9.3
Cashew	16	2.2	0.0– 9.4

TABLE 10.—STRONTIUM-90 CONTENT OF SPICES, 1961–1962

Variety	No. of samples	Picocuries of strontium-90 per kilogram	
		Average	Range
Cinnamon	3	1180	531 –1,680
Thyme leaves	1	885	
Sage leaves	1	618	
Cassia	13	222	4.9–2,590
Cardamon	2	161	98 – 223
Caraway seed	7	96	19 – 206
Hops	5	49	32 – 159
Ginger	3	46	20 – 94
Mustard seed	18	37	8.8– 96
Chili peppers	8	17	1.9– 40

the highest content of strontium-90 of a particular group of foods or individual food, would the level of 200 pc have been approached or exceeded.

On September 1, 1961, the U.S.S.R. resumed nuclear testing, after approximately 2 years of moratorium. This was followed early in 1962 by a test program by the U.S. It became of interest to determine to what extent the injection of additional radioactive debris into the atmosphere would be reflected in this survey. The data were accordingly examined for this effect and, where enough samples were available, arranged in "before" and "after" columns. The results for selected crops appear in table 13. A doubling or more of the strontium-90 concentration can be observed in a number of foods, such as spinach and lettuce harvested after September 1, 1961. Some food items such as strawberries, snap beans, lima beans, and potatoes, actually exhibited less contamination on the average.

TABLE 11.—STRONTIUM-90 CONTENT OF BABY FOODS MANUFACTURED, 1960–1961

Variety	No. of varieties	No. of samples	Picocuries of strontium-90 per kilogram	
			Average	Range
Cereal products	6	40	11	0.1–49
Strained vegetables	7	33	7.0	0.8–25
Strained fruits	6	29	0.9	0.0– 3.9
Meat & poultry products	5	13	0.9	0.1– 2.7

It is quite clear that there is no evidence of a massive increase in fallout radionuclides in foods one year after the resumption of nuclear testing. In view of the relatively large increases in fallout noted one year after the December 1958 moratorium, the findings of this survey are difficult to explain. It should be noted that predictions based on meteorological data overestimated the spring 1962 fallout peak by a sizable margin. It is conjectured that the fallout peak associated with the 1961–62 test series may be delayed until spring 1963.

To compare the surveillance data for broad geographical fallout patterns, the continental U.S. was divided into western, central and eastern areas. The arrangement of the areas by States is given in figure 1. The listings of three categories where sufficient numbers of samples were available for a regional appraisal are included in figure 2. The latter figure also shows that fallout contamination tends to be greater in foods harvested in eastern and central regions, and lowest in the western.

Fallout has been shown to be largely influenced by the amount of rainfall (*5*). Since a large proportion of the western samples originated from irrigated regions of California and the Southwest, we may advance this as the most probable explanation for the generally lower level of contamination.

TABLE 12.—CONTRIBUTION OF SELECTED INDIVIDUAL AND GROUP FOODS TO THE DAILY INTAKE OF STRONTIUM-90, 1960–1962

Items	Strontium-90 concentration		Estimated daily intake		
	Top of range[a] (pc/kg)	Average (pc/kg)	Grams	Strontium-90	
				Top of range (pc)	Average (pc)
Dairy products[b]	140	43	[f]422	59	18
Grain products[c]	447	29	[f]220	100	6.4
Vegetables[d]	299	21	[f]184	55	3.8
Root vegetables	118	8.1	[f]360	42	2.9
Fruits[e]	110	5.8	[f]332	37	1.9
Oranges	27	11	[g]68	1.8	0.75
Lettuce	178	16	[g]33	5.9	0.48
Snap beans	98	18	[g]23	2.3	0.41
Cabbage	68	12	[g]28	1.9	0.28
White potatoes	12	2.4	[g]111	1.3	0.27
Onions	76	7.5	[g]28	2.1	0.21
Sweet potatoes	118	22	[g]7.7	1.0	0.19
Spices	2590	165	[h]0.75	1.2	0.17
Tea	1720	390	[h]0.3	0.5	0.12
Spinach	264	41	[g]3	0.78	0.12
Asparagus	38	6.2	[g]16	0.61	0.10
Egg substance	3.8	1.8	[g]43	0.18	0.09
Coffee	48	16	[h]5	0.24	0.08
Broccoli	100	23	[g]3	0.3	0.07
Tomatoes	11	1.9	[g]30	0.33	0.06
Peas	53	8.0	[g]6	0.32	0.05
Apples	7.0	1.5	[g]31	0.2	0.05
Strawberries	59	15	[g]3	0.18	0.04
Cucumber	17	5.3	[g]6	0.10	0.03
Peaches	12	3.3	[g]8	0.1	0.03
Grapefruit	16	5.1	[g]4	0.06	0.03
Sea food	9.8	0.9	[g]28	0.27	0.03
Cherries	16	6.1	[g]3	0.05	0.02
Bananas	0.5	0.2	[g]36	0.02	0.01
Peppers	11	2.6	[g]3	0.03	0.01

[a] The highest single strontium-90 concentration found in the entire series of analyses on the particular food item.
[b] Cheese, evaporated and dried milk only. Fresh milk not included in analyses.
[c] Whole grains only. Milled, processed derivatives not included in analyses.
[d] Exclusive of tomatoes and root vegetables.
[e] Inclusive of tomatoes.
[f] Food consumption of Households in the United States, U.S.D.A. Report No. 1, 1955; one-person household (all urbanizations).
[g] Prescribed annual and daily allowances of food groups in military composite ration for 1960 (see ref 6).
[h] Based on an estimated daily use of 1.5 grams tea leaves for making beverage and an estimate of 20% extraction of strontium-90.
[i] Based on military composite ration of 25 grams per day (*see ref. 6*) and an estimate of 20% extraction of strontium-90.

TABLE 13.—STRONTIUM-90 CONTENT OF AGRICULTURAL PRODUCTS HARVESTED BEFORE AND AFTER RESUMPTION OF ATMOSPHERIC TESTING

Variety	No. of samples	*Before:* 1960 to Sept. 1961 (Picocuries of strontium-90 per kilogram)		No. of samples	*After:* Sept. 1961 thru 1962 (Picocuries of strontium-90 per kilogram)	
		Average	Range		Average	Range
Strawberries	43	16	0.9–59	17	12	2.0– 37
Peaches	27	1.8	0.4– 7.3	41	4.3	0.4– 14
Tomatoes	45	1.4	0.1– 5.3	54	2.2	0.1– 11
Apples	25	1.1	0.1– 3.5	33	1.1	0.2– 7.0
Spinach	24	13	2.8–67	36	59	2.9–264
Soy beans	9	26	13 –42	23	49	11 –272
Lettuce	49	4.3	0.7–18	90	21	0.8–178
Celery	54	7.4	0.9–31	51	15	0.7– 56
Snap beans	62	20	2.0–98	40	14	0.3– 85
Cabbage	11	5.6	1.6–13	126	11	0.3– 78
Peas	22	4.4	0.7– 8.7	40	10	0.0– 43
Lima beans	11	8.5	2.7–28	27	4.5	0.4– 19
Onions	34	4.1	0.1–45	46	10	0.5– 70
Carrots	35	4.0	0.5–13	40	5.7	0.9– 25
Potatoes	25	2.9	0.7– 11	116	2.2	0.0– 12

Before any formal program with industrial participants was planned, an investigation was conducted to determine what effects such mechanical operations as washing, culling, peeling, and milling would have on the strontium-90 content of raw agricultural products. When certain raw products were sampled, the processed counterparts, either frozen or canned, were also analyzed. Each individual sample of a raw agricultural product was identified by lot number as the precursor of a particular processed sample. The results, shown in table 14, indicate that canning or freezing, together with the associated preparative mechanical operations, remove from 19 to 62 percent of

TABLE 14.—EFFECT OF PROCESSING ON THE STRONTIUM-90 CONTENT OF VEGETABLES AND FRUITS

Product	No. of paired samples	Picocuries strontium-90 per kilogram				Percent reduction
		Raw		Canned or frozen		
		Average	Range	Average	Range	
Spinach	34	23	2.8–96	18	1.8–90	22
Snap beans	38	16	1.1–98	6.1	0.4–30	62
Carrots	25	6.2	0.8–21	5.0	0.7–23	19
Tomatoes	41	1.4	0.1– 5.1	1.1	0.1– 4.6	21
Peaches	14	1.4	0.4– 4.0	0.7	0.1– 2.1	50

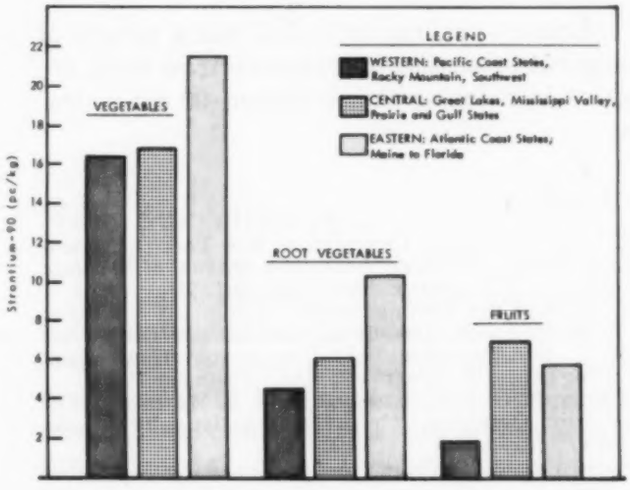

FIGURE 2.—REGIONAL DISTRIBUTION OF STRONTIUM-90 RAW AGRICULTURAL PRODUCTS IN THE U.S., 1960–1962

TABLE 15.—DISTRIBUTION OF STRONTIUM-90 IN CERTAIN AGRICULTURAL PRODUCTS

[Picocuries strontium-90 per kilogram]

Food type	Number of samples	Strontium-90	
		Average	Range
Wheat			
Berry	*38	22	3.3– 58
Bran	32	68	9.6– 168
Flour	38	4.4	0.6– 13
Rice			
Whole grain	10	4.9	1.1– 8.3
Milled	10	0.7	0.1– 1.7
Corn			
Whole grain	18	1.6	0.0– 4.6
Meal	18	1.3	0.0– 4.4
Beans, lima			
Bean	23	7.8	0.6– 28
Pod	23	39	3.7– 172
Apples			
Flesh	15	0.9	0.1– 2.6
Peel	8	1.4	0.6– 3.5
Core	14	3.8	0.8– 14
Eggs			
Substance	27	1.8	0.3– 3.8
Shell	21	407	39 –1,300

* Indicates number of paired or related samples.

strontium-90 from the raw product. Table 15 shows that there are some interesting differences in distribution of strontium-90 within many food parts. For example, milling, which separates the outer coat or branlike layer from grains, is also very effective in reducing the strontium-90 content. Unequal distribution of strontium-90 can also be seen in products like apples, lima beans and eggs, the latter most remarkably so, with egg shell containing over one hundred times as much as the egg substance. Here, the close association of strontium with calcium is obvious.

Cesium-137 of Individual Foods and Food Groups

Although fewer samples were analyzed for cesium-137 than for strontium-90 content, the results in table 16 show that the level of cesium-137 in foods is, on the average, about 5 times that of strontium-90 (of table 1). Cesium-137 distribution in the food chain is generally similar to that of strontium-90 as found in tea, spices, sea food, eggs, and root vegetables, but cesium-137 is relatively higher in such items as leafy vegetables.

Table 17 shows the estimated intakes of cesium-137. The Federal Radiation Council has not issued any guidance on daily intake of cesium-137 but one can deduce from maximum permissible concentrations, quoted in Handbook 69 of the National Committee on Radiation Protection, that a cesium-137 intake guide would be of the order of 4,000 pc per day.[2] Using this value for orientation, it can be seen in table 17 that the top of the range of cesium-137 concentrations recorded was as follows: vegetables, 1,020 pc; dairy products, 548 pc; root vegetables, 370 pc; fruits, 184 pc; and grain products, 138 pc. Thus, even in the unlikely situation of all food groups being contaminated to the maximum extent noted in table 17, the daily dietary intake level of 4,000 picocuries would not be observed.

Summary

Within the frame of reference indicated by the Federal Radiation Council, this survey has uncovered no foods which, on the basis of their daily

[2] This figure represents a general population cesium-137 intake guide, estimated by dividing the 168-hour occupational (MPC)$_w$ by 100 and applying a daily intake of two liters of water.

TABLE 16.—CESIUM-137 CONTENT OF HUMAN FOODS PRODUCED AND HARVESTED IN 1960–1962

Type of food	No. of varieties	No. of samples	Picocuries of cesium-137 per kilogram	
			Average	Range
Leafy vegetables[1]	6	20	1,470	[15]N.D.–5,540
Tea[2]	2	20	1,290	210–4,960
Spices[3]	8	20	784	N.D.–3,150
Coffee[4]	2	7	431	320– 652
Legumes[5]	9	34	264	N.D.–1,940
Nuts[6]	6	34	246	N.D.–1,180
Cocoa beans	1	2	142	141– 142
Dairy products[7]	2	20	133	N.D.–1,300
Grains[8]	4	55	132	N.D.– 625
Brassicae[9]	3	17	124	N.D.–1,030
Rice	1	4	101	N.D.– 329
Grain products[10] (flour, meal, bran)	7	28	95	N.D.– 500
Root vegetables[11]	4	13	79	N.D.– 413
Fruits[12]	20	51	79	N.D.– 553
Corn	1	18	68	1.0– 142
Sea food[13]	7	27	50	N.D.– 205
White potatoes	1	14	38	N.D.– 291
Egg substance[14]	1	6	12	3– 27
Processed baby foods (junior)				
Strained meats	3	4	44	22– 65
Strained vegetables	4	6	33	3.6– 125
Strained fruits	1	1	2.6	
Organic calcium sources				
Egg shells	1	3	396	N.D.–1,170

[1] Lettuce, spinach, parsley, collards, celery, and mustard greens.
[2] Black and green tea.
[3] Cardamom, cassia, chili peppers, caraway seed, mustard seed, thyme leaves and dried hops.
[4] Ripe and green coffee beans.
[5] Dried red, pinto, snap, navy, green, lima, peas, kidney beans and soy beans.
[6] Almonds, Brazil nuts, cashews, peanuts, pecans and walnuts.
[7] Milk (non-fat dried milk) and cheeses (cheddar, cottage, etc.).
[8] Wheat, oats, barley and rye.
[9] Cabbage, Brussel sprouts and broccoli.
[10] Bran, flour, corn meal, oat flour, soybean meal and soya flour.
[11] Carrots, turnips, onions and sweet potatoes.
[12] Apples, apricots, bananas, cherries, cranberries, cucumbers, dates, figs grapes, grapefruit, nectarines, oranges, peaches, pears, pineapple, plums, pumpkin, squash, raspberries and tomatoes.
[13] Clams, crabmeat, haddock, lobster and lobster tails, sardines, shrimp and tuna fish.
[14] Without shells.
[15] ND indicates not detectable.

intake of strontium–90 or cesium–137, would approach the suggested daily limits of intake. The first year following resumption of atmospheric testing was not marked by dramatic increases of strontium–90 in foods, although some sporadic higher concentrations were noted in leafy vegetables.

Fallout contamination of foods ranks higher in eastern and central portions of the U.S. than in the West—an effect believed to be associated with the amount of rainfall.

Preliminary findings indicated that a variety of mechanical processing operations on raw foods are effective in reducing the strontium–90 concentration.

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(1) U.S. Atomic Energy Commission, New York Operations Office: *Health and Safety Laboratory Manual of Standard Procedures, NYO–4700:*E–38–01 (March 1957).

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(3) Turner, R. C. J. M. Radley, and W. V. Mayneord: The Naturally Occurring Alpha Ray Activity of Foods, *Health Physics 1:*268–75 (1958).

(4) Federal Radiation Council press release dated September 10, 1962.

(5) Federal Radiation Council: *Estimates and Evaluation of Fallout in the U.S. from Nuclear Weapons Testing Conducted through 1962, Report No. 4,* Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., (May 1963) price 30 cents.

(6) U.S. Army Subsistence Center: *Annual Food Plan for the Army/Air Force, 1960, In continental U.S.,* Attn: Chief, Menu Planning Div., 1819 W. Pershing Rd., Chicago.

TABLE 17.—CONTRIBUTION OF SELECTED INDIVIDUAL AND GROUP FOODS TO THE DAILY INTAKE OF CESIUM–137

Item	Cesium–137 concentration		Estimated daily intake		
	Top of range[a] (pc/Kg)	Average (pc/Kg)	Grams	Cesium–137	
				Top of range (pc)	Average (pc)
Vegetables[b]	5,540	570	[f]184	1,020	105
Dairy products[c]	1,300	133	[f]422	548	56
Root vegetables	1,030	79	[f]360	370	28
Fruits[d]	553	79	[f]332	184	26
Grain products[e]	625	115	[f]220	138	25
White potatoes	291	38	[g]111	32	4.2
Coffee	652	431	[h]5	3.3	2.2
Sea food	205	50	[g]28	5.7	1.4
Spices	15,700	784	[f]0.75	11	0.59
Egg substance	27	12	[g]43	1.1	0.52
Tea	25,700	1,290	[i]0.3	7.5	0.39
Rounded sums			1,710	2,320	249

[a] The highest single cesium–137 concentration found in the entire series of analyses on the particular food item.
[b] Exclusive of tomatoes and root vegetables.
[c] Cheese, evaporated and dried milk only. Fresh milk not included in analyses.
[d] Inclusive of tomatoes.
[e] Whole grains only. Milled, processed derivatives not included in analyses.
[f] Prescribed annual and daily allowances of food groups in military composite ration for 1960 (*See* note h).
[g] Food Consumption of Households in the United States—1 person household (all urbanizations). U.S.D.A. Report #1 (1955).
[h] Based on an estimate of 20% extraction of cesium–137 and *Annual Food Plan for the Army/Air Force In Continental U.S., 1960,* U.S. Army Subsistence Center, Attn: Chief, Menu Planning Div., 1819 W. Pershing Rd., Chicago, Ill.
[i] Based on an estimated daily use of 1.5 grams tea leaves for making beverage and an estimate of 20% extraction of cesium–137.

SECTION III.—MILK

Milk Surveillance

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segement of the U.S. population and contains most of the radionuclides occurring in the environment which have been identified as being biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to handle, is easily analyzed, and samples which are representative of milk consumption in any area can be readily obtained.

PASTEURIZED MILK NETWORK
May 1963

Division of Radiological Health and
Division of Environmental Engineering and
Food Protection, Public Health Service

The Public Health Service pasteurized milk radionuclide surveillance program had its origin in a raw milk monitoring network established by the Service in 1957. One of the primary objectives of this network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this earlier network led to the activation of a pasteurized milk sampling program comprising 46 stations in July 1960. The 46 stations were selected to provide nationwide surveillance of milk production and consumption areas.

As further needs developed, more milk sampling points were added through July 1962, when the total number of stations reached was 62. Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each of these stations. After collection, the composites are preserved with formaldehyde and are sent for analysis to the Southwestern, Southeastern, or Northeastern Radiological Health laboratories of the Public Health Service. Approximately 3–6 days after sample collection, any results from the gamma analyses for iodine–131 which indicate concentrations of this radionuclide greater than 100 pc/liter are made available to States for possible public health action. Complete analytical results are available 6 to 7 weeks after sample collection; publication in *Radiological Health Data* follows 3 to 4 months after sample collection.

Sampling and Compositing Procedures

The method of compositing specifies that each station's sample be composited of subsamples from each milk processing plant in proportion to the plant's sales in the community served. At most stations, the composited sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, sampling was done twice a

TABLE 1.—RADIOACTIVITY IN PASTEURIZED MILK, MAY 1963

[Average radioactivity concentrations in pc/liter]

Sampling locations		Calcium (g/liter)		Strontium–89		Strontium–90		Iodine–131		Cesium–137		Barium–140	
		First quarter 1963	Avg. for month	First quarter 1963	Avg. for month	First quarter 1963	Avg. for month	First quarter 1963	Avg. for month	First quarter 1963	Avg. for month	First quarter 1963	Avg. for month
Ala:	Montgomery	1.26	1.22	85	130	18	26	<10	<10	50	100	10	<10
Alaska:	Palmer	1.19	1.16	20	30	11	14	10	<10	65	50	10	<10
Ariz:	Phoenix	1.20	1.18	20	30	4	6	<10	<10	20	20	<10	<10
Ark:	Little Rock	1.23	1.22	125	215	34	51	20	<10	90	210	20	<10
Calif:	Sacramento	1.23	1.21	25	130	4	26	10	<10	30	95	10	<10
	San Francisco	1.26	1.21	85	200	8	25	10	<10	35	125	10	<10
Colo:	Denver	1.29	1.24	15	20	11	12	20	<10	65	55	<10	<10
Conn:	Hartford	1.11	1.09	<5	30	12	19	<10	<10	65	110	<10	<10
Del:	Wilmington	1.13	1.00	5	65	17	31	<10	<10	70	120	<10	<10
D.C:	Washington	1.22	1.16	10	120	15	25	<10	<10	60	110	<10	<10
Fla:	Tampa	1.24	1.20	50	40	14	14	20	<10	135	200	<10	<10
Ga:	Atlanta	1.24	1.20	100	190	21	36	10	<10	85	190	20	<10
Hawaii:	Honolulu	1.14	1.12	55	75	8	10	20	<10	55	65	10	<10
Idaho:	Idaho Falls	1.25	1.20	10	60	11	16	10	<10	75	85	<10	<10
Ill:	Chicago	1.13	1.02	<5	25	16	19	<10	<10	70	70	<10	<10
Ind:	Indianapolis	1.15	1.05	10	70	16	35	<10	<10	60	100	<10	<10
Iowa:	Des Moines	1.23	1.20	15	200	14	41	10	<10	65	110	10	<10
Kans:	Wichita	1.25	1.18	20	60	12	20	10	<10	50	60	10	<10
Ky:	Louisville	1.22	1.20	35	175	20	34	<10	<10	55	110	<10	<10
La:	New Orleans	1.27	1.27	265	170	37	40	20	<10	120	180	30	<10
Maine:	Portland	1.14	1.01	<5	20	20	25	<10	<10	105	120	<10	<10
Md:	Baltimore	1.23	1.16	5	120	14	26	<10	<10	65	130	<10	<10
Mass:	Boston	1.14	1.02	<5	30	19	23	<10	<10	95	120	<10	<10
Mich:	Detroit	1.16	1.03	<5	20	18	21	<10	<10	75	75	<10	<10
	Grand Rapids	1.16	1.07	5	20	15	16	10	<10	75	80	<10	<10
Minn:	Minneapolis	1.20	1.20	15	50	17	24	10	<10	110	100	10	<10
Miss:	Jackson	1.33	1.29	230	205	32	38	20	<10	80	145	30	<10
Mo:	Kansas City	1.23	1.26	25	170	14	40	<10	<10	50	105	10	<10
	St. Louis	1.24	1.18	20	125	11	28	10	<10	60	95	20	<10
Mont:	Helena	1.18	1.26	20	65	13	20	10	<10	90	100	20	<10
Nebr:	Omaha	1.25	1.24	20	120	14	30	10	<10	65	80	10	<10
Nev:	Las Vegas	1.18	1.16	10	25	6	9	<10	<10	45	40	10	<10
N.H.:	Manchester	1.16	1.07	<5	30	18	24	10	<10	110	130	<10	<10
N.J:	Trenton	1.14	1.03	<5	40	13	25	<10	<10	65	105	<10	<10
N. Mex:	Albuquerque	1.23	1.15	15	40	4	10	<10	<10	30	35	10	<10
N.Y:	Buffalo	1.11	1.03	5	30	16	21	<10	<10	85	90	<10	<10
	New York	1.12	1.05	<5	25	16	22	<10	<10	65	90	<10	<10
	Syracuse	1.12	1.05	<5	25	13	21	<10	<10	65	80	<10	<10
N.C:	Charlotte	1.27	1.30	30	140	22	32	<10	<10	60	120	<10	<10
N. Dak:	Minot	1.21	1.20	15	190	23	56	<10	<10	85	100	20	<10
Ohio:	Cincinnati	1.11	1.03	15	80	17	35	<10	<10	55	90	<10	<10
	Cleveland	1.12	1.07	<5	40	14	24	<10	<10	60	80	<10	<10
Okla:	Oklahoma City	1.23	1.20	60	165	20	30	20	<10	55	125	10	<10
Ore:	Portland	1.25	1.24	55	210	11	48	<10	<10	70	180	20	<10
Pa:	Philadelphia	1.13	1.02	5	70	18	30	<10	<10	65	130	<10	<10
	Pittsburgh	1.13	1.06	5	45	18	22	<10	<10	80	100	<10	<10
P.R:	San Juan	1.20	1.17	135	100	12	19	20	<10	65	130	20	<10
R.I:	Providence	1.13	1.01	5	45	16	29	<10	<10	75	115	<10	<10
S.C:	Charleston	1.26	1.25	105	140	23	28	20	<10	80	110	20	<10
S. Dak:	Rapid City	1.00	0.92	25	100	13	27	10	<10	80	90	<10	<10
Tenn:	Chattanooga	1.29	1.22	75	235	23	43	<10	<10	65	165	10	<10
	Memphis	1.26	1.23	100	190	23	41	10	<10	50	110	20	<10
Tex:	Austin	1.22	1.12	50	50	*8	8	10	<10	30	45	<10	<10
	Dallas	1.25	1.16	110	140	20	28	20	<10	60	110	20	<10
Utah:	Salt Lake City	1.26	1.22	15	30	12	19	10	<10	100	90	10	<10
Vt:	Burlington	1.11	1.04	<5	25	16	19	<10	<10	85	100	<10	<10
Va:	Norfolk	1.25	1.20	30	95	17	26	<10	<10	65	120	<10	<10
Wash:	Seattle	1.24	1.17	30	190	10	35	10	<10	75	190	10	<10
	Spokane	1.31	1.32	15	160	12	36	10	<10	85	150	10	<10
W. Va:	Charleston	1.23	1.18	15	180	19	40	<10	<10	50	115	<10	<10
Wis:	Milwaukee	1.14	1.04	10	20	11	22	<10	<10	65	75	<10	<10
Wyo:	Laramie	1.24	1.24	20	70	12	23	<10	<10	95	105	20	<10
Network average		1.20	1.15	37	95	15.6	26.5	<10	<10	70	107	<10	<10

week at nearly all stations, and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a week.

All surveillance data are subject to continuing review and evaluation to observe unusual patterns or concentrations which may require immediate attention. Sampling frequency and schedules of analyses are adjusted to meet changing conditions.

Analytical Errors in Radionuclide Measurements

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectroscopy,[1] while strontium–89 and strontium–90 concentrations are determined by radiochemical

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

TABLE 2.—DISTRIBUTION OF SAMPLING STATIONS IN VARIOUS RANGES OF RADIONUCLIDE CONCENTRATIONS IN MILK, MAY 1963

Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
Range (pc/liter)	Number of stations	Range (pc/liter)	Number of stations	Range (pc/liter)	Number of stations	Range (pc/liter)	Number of stations	Range (pc/liter)	Number of stations
<5– 30	17	<1– 8	2	<10	62	<5– 40	3	<10	62
35– 60	10	9–16	8			45– 80	12		
65– 90	7	17–24	19			85–120	32		
95–120	7	25–32	17			125–160	8		
125–150	5	33–40	10			165–200	6		
155–180	6	41–48	4			205–240	1		
185–210	8	49–56	2						
>210	2								

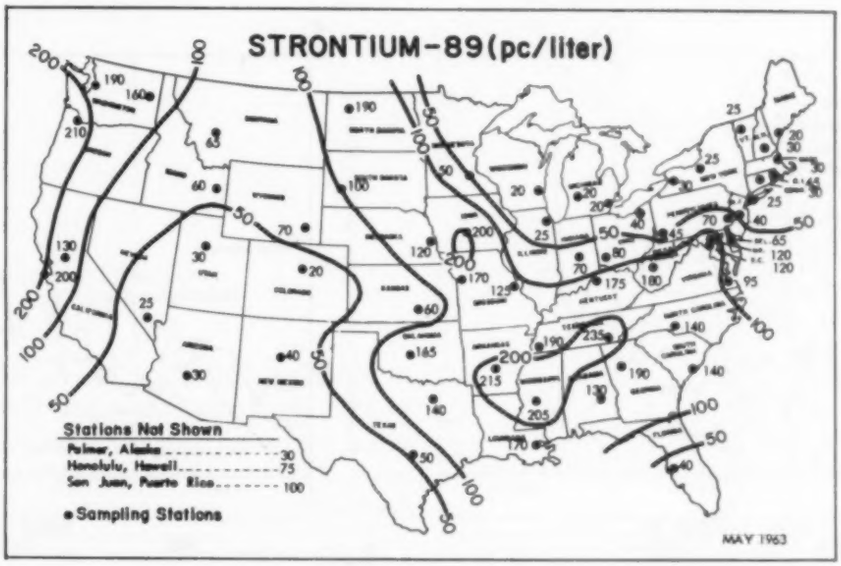

FIGURE 1.—STRONTIUM-89 CONCENTRATIONS IN PASTEURIZED MILK, MAY 1963

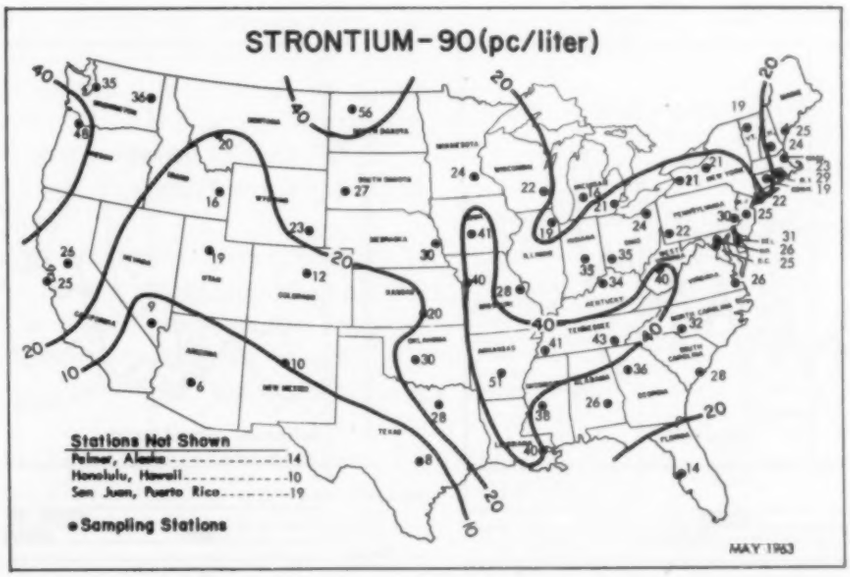

FIGURE 2.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK, MAY 1963

procedures. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation is relatively high. The variation is dependent upon the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides, and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for low background beta determinations are used. The minimum detectable concentration is defined as that concentration at which the statistical two-standard-deviation analytical error is 100 percent of the measured concentration (*1*). Accordingly the minimum detectable concentrations in units of pc/liter are Sr^{89}, 5; Sr^{90}, 1; I^{131}, 10: Cs^{137}, 5; and Ba^{140}, 10.

Data Presentation

Table 1 presents summaries of the analyses for May 1963 (April 28–May 25, 1963). When a radionuclide is reported by a laboratory as being below the minimum detectable concentration, one-half of this value is used in calculating the monthly average. A similar procedure is used for the network average.

Although no data are presented on the stable potassium concentrations in milk, analysis has

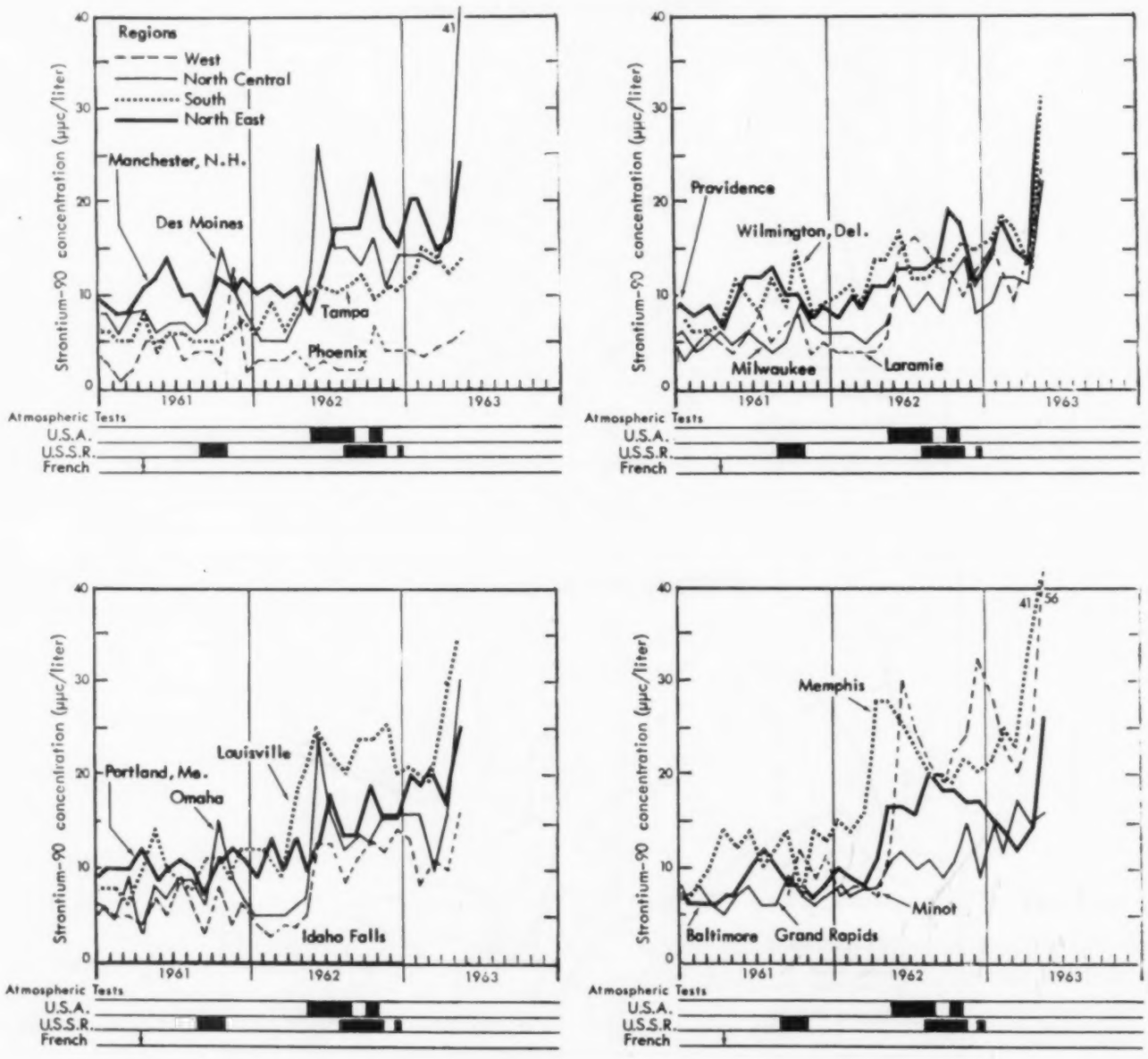

FIGURE 3.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK, 1961–MAY 1963

indicated that the usual range of concentrations is from 1.3 to 1.8 grams/liter. In May, for example, 2, 22, 11, 23, 3, and 1 stations recorded respective monthly average potassium concentrations of 1.3, 1.4, 1.5, 1.6, 1.7 and 1.8 grams/liter. One station recorded 1.1 grams/liter.

Figures 1 and 2 are isoconcentration maps showing the estimated radionuclide concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. In order to show numerically the distribution of the network's stations versus radionuclide concentrations in milk, table 2 has been prepared using the monthly average data shown in table 1.

Selected Monthly Strontium–90 Profiles

Continuing the practice followed in previous issues of RHD, the average monthly strontium–90 concentrations in pasteurized milk from 16 selected cities in the sampling program are presented (see figure 3). Each individual graph shows the strontium–90 concentrations in milk from one city in each of the four U.S. Bureau of Census regions. This method of selection permits the graphical presentation of data for each city in the network at least twice a year.

REFERENCE

(*1*) Division of Radiological Health, Public Health Service: Pasteurized Milk Network, February 1963, *Radiological Health Data*, 4:291-6, Superintendent of Documents, Government Printing Office, Washington 25, D.C. (June 1963).

INDIANA MILK NETWORK
May 1963

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radiological analysis in September 1961. Indiana was geographically divided into five major milksheds, and one large dairy within each milkshed was selected as a sampling station (see figure 4).

The milk samples are routinely analyzed for iodine–131, cesium–137, barium–140, strontium–89, and strontium–90. Analyses for the gamma emitters iodine–131, cesium–137, and barium–140 are conducted on a weekly basis except when iodine–131 results exceed 100 pc/liter, at which time the frequency of sampling is increased. Strontium–89 and strontium–90 analyses are performed monthly on samples which are composited from weekly aliquots.

The ion exchange analytical procedure (*1*) is used for strontium–89 and strontium–90 analyses. A 512-channel pulse height analyzer and shielded 4 x 4-inch sodium iodide crystal are used for the gamma analysis of iodine–131, cesium–137, and barium–140.

The monthly averages of the data obtained for the individual sampling stations and the State averages are reported in table 3. The State average is an arithmetic average of the station values.

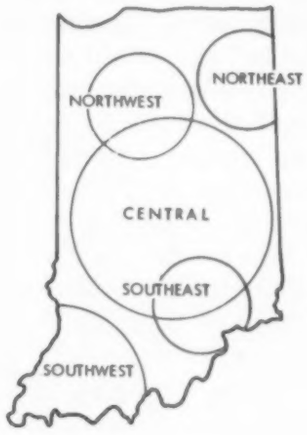

FIGURE 4.—INDIANA MILK SAMPLING LOCATIONS

TABLE 3.—RADIONUCLIDES IN INDIANA MILK, MAY 1963

[Concentrations in pc/liter]

Sampling location	Strontium -89	Strontium -90	Iodine -131	Cesium -137	Barium -140
Northeast	85	24	<10	90	<10
Southeast	100	34	<10	100	<10
Central	90	30	<10	85	<10
Southwest	40	32	<10	70	<10
Northwest	90	28	<10	105	<10
State average	80	30	<10	90	<10

REFERENCE

(*1*) Porter C., D. Cahill, R. Schneider, P. Robbins, W. Perry, and B. Kahn: Determination of Strontium-90 in Milk by an Ion Exchange Method, *Analytical Chemistry* 33:1306–8 (September 1961).

NEW YORK MILK NETWORK
April 1963

Division of Environmental Health Services
State of New York Department of Health

Milk samples, collected routinely from six cities —Albany, Buffalo, Massena, Newburgh, New York City, and Syracuse (figure 5), are analyzed for radionuclide content by the State of New York Department of Health. Pasteurized milk samples are collected daily and composited weekly for the determination of strontium–89, strontium–90, iodine–131 and cesium–137 at all stations except Massena, where samples are composited bi-weekly and at New York City where one daily milk sample representing the total milk supply for that day is obtained and analyzed once per week. Samples are obtained from processing plants except at Albany, where the daily sample is obtained from a marketing point. During periods when cows are no longer on stored feed, the sample from Albany is analyzed for iodine–131 daily. In the event that any city reports iodine–131 concentrations exceeding 100 pc/liter, increased surveillance is undertaken.

The matrix method (*1*) is used for the analysis of spectral data to determine the concentrations of gamma-emitting nuclides in milk. With this method, the individual nuclide contributions to the gamma spectrum are separated by solution of simultaneous equations describing the spectral interferences.

TABLE 4.—RADIONUCLIDES IN NEW YORK MILK, APRIL 1963

[Concentrations in pc/liter]

Sampling location	Strontium –89	Strontium –90	Iodine –131	Cesium –137
Albany	4	8	<20	49
Buffalo	7	7	<20	37
Massena	5	9	<20	73
Newburgh	13	7	<20	23
New York City	9	8	23	<20
Syracuse	5	6	<20	<20

FIGURE 5.—NEW YORK MILK SAMPLING LOCATIONS

The analytical procedure for strontium–89 and strontium–90 is based on ion exchange methods. Cations (including radiostrontium) are eluted from the ion exchange resin with sodium chloride solution, strontium isotopes are gathered by means of sodium carbonate, isolated by means of ethylenediaminetetraacetic acid (EDTA), and radiostrontium is counted with a low background beta counter having an 0.8 mg/cm² window. The strontium–90 portion is differentially estimated by a second count 40 hours later to determine the rate of growth of its daughter product, yttrium–90. The monthly average radionuclide concentrations in milk are shown in table 4.

REFERENCE

(*1*) Kahn, B., et al.: *Rapid Methods for Estimating Fission Product Concentrations in Milk, Public Health Service Publication No. 999–R–2*, (March 1963). Single copies available on request.

OREGON MILK NETWORK
March–June 1963

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health conducts milk monitoring at eight major milk-producing centers throughout the State of Oregon, as shown in figure 6. The half-gallon samples of packaged milk are collected on a monthly basis State-wide by the Oregon Department of Agriculture and weekly in the Portland area by the City of Portland. Milk sampling frequency is accelerated to a weekly schedule at those locations having milk concentrations in excess of 100 pc/liter for iodine–131 or 500 pc/liter for cesium–137 (suggestive of elevated strontium–90 concentrations). The samples are forwarded to the Oregon State Board of Health radiation laboratory for iodine–131, cesium–137, and barium–140 analyses. Gamma analyses are performed utilizing a 3″ x 3″ sodium iodide scintillation crystal and a 512-channel pulse-height analyzer system. Samples are normally counted for 100 minutes. The minimum detectable concentrations for iodine-131, cesium–137, and barium–140 are 15 pc/liter. The minimum detectable concentration is defined to be that amount of activity which, in the same counting time, will exceed the background by 3σ (counting error) of the background.

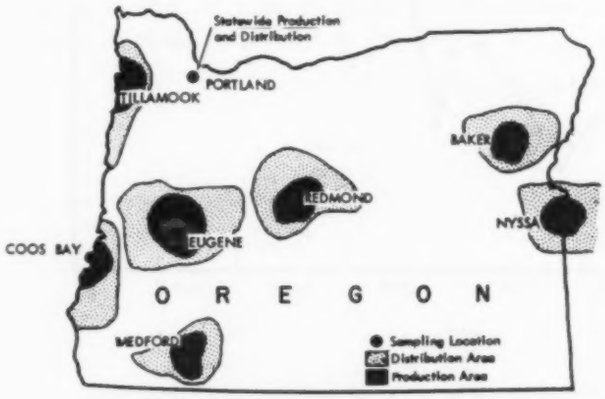

FIGURE 6.—OREGON PASTEURIZED MILK NETWORK SAMPLING LOCATIONS SHOWING PRODUCTION AND DISTRIBUTION AREAS

To maintain a check on the analytical procedures and instrument calibration, a portion of the official U.S. Public Health Service composite pasteurized milk sample from Portland is obtained on a weekly basis for analysis. The cesium–137 data are compared with the Public Health Service data in figure 7.

Table 5 presents the Oregon milk surveillance data on iodine–131, cesium–137 and barium–140 for March through June 1963. The Portland composite sample represents contributions from nearly all milksheds in Oregon, plus some in Washington State. During the period reported, iodine–131 again became detectable. The fact that iodine–131 was detectable is supported by results of analyses of a May 8 milk sample from Coos Bay that was analyzed by both the Oregon State Board of Health and the Public Health Service. Iodine–131 concentrations of 30 and 20 pc/liter were reported, respectively.

During heavy coastal rains in April, cesium–137 concentrations began to increase, reaching a peak during May at most Oregon milk sampling locations. Following the increased cesium–137 concentrations during April, weekly sampling of milk

TABLE 5.—IODINE-131, CESIUM-137, AND BARIUM-140 CONCENTRATIONS IN OREGON MILK, MARCH-JUNE 1963

[Average concentrations in pc/liter]

Sampling location	Iodine-131				Cesium-137				Barium-140			
	Mar.	Apr.	May	Jun.	Mar.	Apr.	May	Jun.	Mar.	Apr.	May	Jun.
Baker	<15	<15	<15	20	50	50	90	205	<15	<15	<15	<15
Coos Bay	<15	40	40	15	65	340	460	240	<15	<15	<15	<15
Eugene	<15	<15	15	<15	55	65	200	165	<15	<15	<15	<15
Medford	<15	15	<15	20	50	95	200	230	<15	<15	20	<15
Nyssa	<15	<15	<15	<15	45	55	85	170	<15	<15	<15	<15
Portland (composite)	<15	20	<15	15	75	130	215	190	<15	<15	<15	<15
Portland (Local Producer)	<15	20	15	<15	70	125	235	175	<15	<15	20	<15
Redmond	<15	<15	20	<15	60	60	105	105	<15	<15	<15	<15
Tillamook	<15	20	20	20	85	215	380	305	<15	<15	15	<15

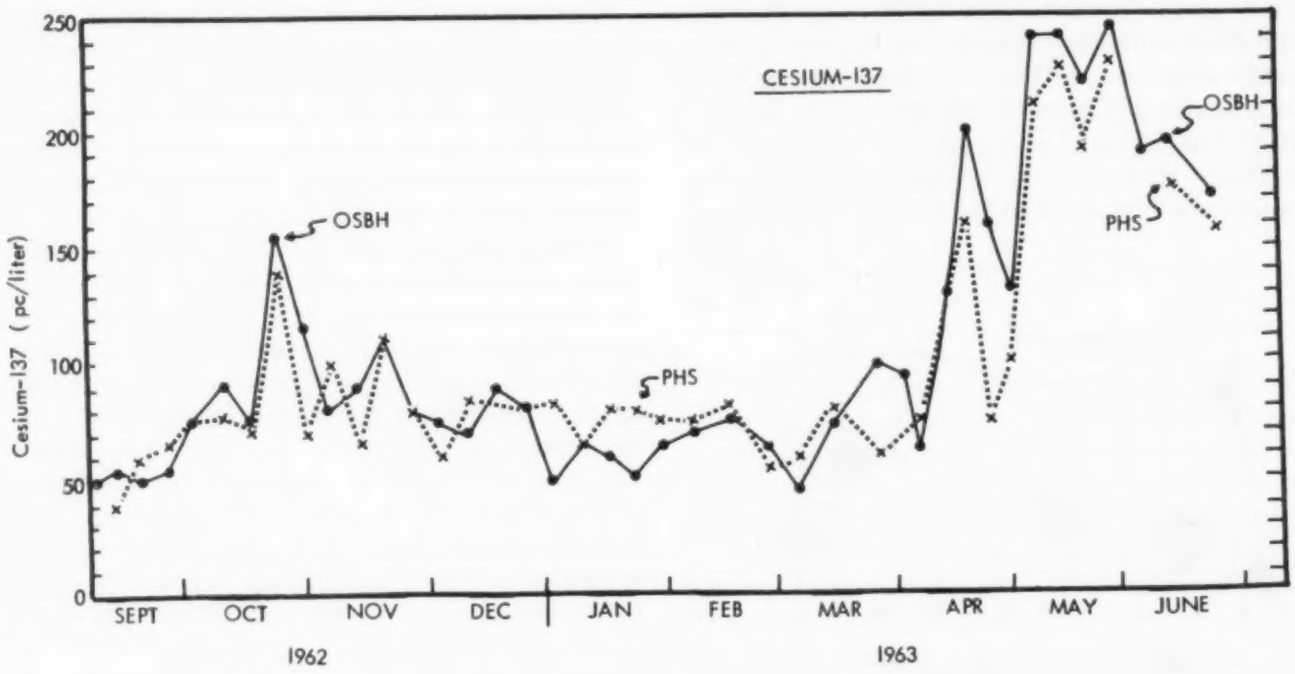

FIGURE 7.—COMPARISON OF PUBLIC HEALTH SERVICE AND OREGON STATE BOARD OF HEALTH SPLIT MILK SAMPLE ANALYSES FOR PORTLAND, OREGON

TABLE 6.—STRONTIUM-89 AND STRONTIUM-90 CONCENTRATIONS IN OREGON MILK, MARCH-MAY 1963

[Average concentrations in pc/liter]

Sampling location	Strontium-89			Strontium-90		
	Mar.	Apr.	May	Mar.	Apr.	May
Coos Bay			885			162
Portland (composite)	55		210	12		48
Tillamook			435			74

was initiated in the first week in May at Coos Bay and Tillamook, where the highest concentrations of cesium-137 in the State were observed. Samples from these stations were shipped to the Public Health Service for radiostrontium analysis. The data in table 6 indicate that significant increases in strontium-89 and strontium-90 concentrations occurred in May.

CANADIAN MILK NETWORK[1]
April 1963

Radiation Protection Division
Department of National Health and Welfare,
Ottawa, Canada

In January 1963, the Canadian Department of National Health and Welfare substituted the radioanalysis of fresh liquid milk for the analysis of powdered milk. The Department analyzed milk powders from November 1955 through December 1962, but liquid whole milk had been monitored since April 1962 for iodine–131 only.

With this change, it has been possible to choose milk sampling locations in the same areas as the air and precipitation stations. This permits the observation of a number of environmental variables which may effect the radionuclide levels in milk. In addition, it is now possible to report radionuclide concentrations in terms of the activity per liter of milk as well as per gram of calcium in milk.

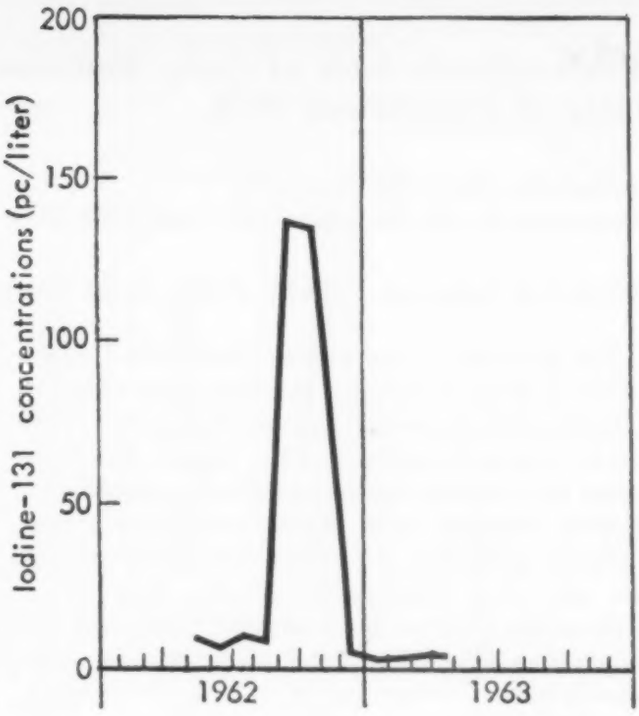

FIGURE 8.—IODINE–131 CONCENTRATIONS IN WHOLE MILK

TABLE 7.—RADIONUCLIDES IN CANADIAN WHOLE MILK, APRIL 1963

Station	Calcium (g/liter)	Strontium–89 (pc/liter)	Strontium–90 (pc/liter)	Iodine–131 (pc/liter)	Cesium–137 (pc/liter)
Calgary	1.25	24	19.0	0	82
Edmonton, Alta	1.23	20	16.2	—	89
Fort William	1.20	7	23.5	—	106
Fredericton	1.30	9	31.6	—	172
Halifax	1.26	9	22.7	1	160
Montreal	1.21	12	12.3	—	64
Ottawa	1.21	9	10.3	5	49
Quebec	1.20	7	21.2	3	117
Regina	1.19	12	17.3	—	56
Saint John's, Nfld	1.21	15	18.9	—	94
Saskatoon	1.24	55	16.0	1	50
Sault Ste. Marie	1.19	13	14.2	1	60
Toronto	1.25	15	8.7	—	64
Vancouver	1.27	91	23.6	3	152
Windsor	1.26	14	9.6	2	48
Winnipeg	1.21	14	14.1	1	67
Average	1.23	20	17.5	2	80

[a] A dash indicates no analysis is made for these cities.

A detailed discussion of the sampling and radiochemical procedures employed for milk analyses may be found in the Department's publications (*1*, *2*). Table 7 presents the results of the measurements of strontium–89, strontium–90, cesium–137, and iodine–131 in Canadian liquid whole milk for April. Figure 8 shows the iodine–131 variation since April 1962.

It should be emphasized that the interpretation of fallout data in relation to health is a complex problem. In comparing the concentration levels in a particular medium with the so-called Maximum Permissible Concentrations (MPC's) as established by the International Commission on Radiological Protection (*3*), it is necessary to keep in mind that the MPC values refer to conditions of continuous exposure over a lifetime. Therefore, the average levels over an extended period, such as one year, represent a better basis for comparison than do individual levels at any specific time.

[1] Data from *Radiation Protection Programs*, Radiation Protection Division, Canadian Department of National Health and Welfare.

REFERENCES

(*1*) Radiation Protection Division, Department of National Health and Welfare, Ottawa, Canada: *The Preliminary Report on the Measurement of Radioactive Strontium in Canadian Milk Powder Samples, CNHW–RP–1*, (July (1958).

(*2*) Mar, Peter G.: *Outline of Procedure for the Radiochemical Analysis of Dried Milk Powders for Strontium and Yttrium, RPD–5*, Radiation Protection Division, Department of National Health and Welfare (June 1, 1960).

(*3*) International Commission on Radiological Protection: *Report of Committee II on Permissible Dose for Internal Radiation*, Pergamon Press, New York (1959).

Twelve-Month Sum of Daily Radionuclide Content of One Liter of Pasteurized Milk

Iodine–131: July 1962–June 1963
Strontium–89 and Strontium–90: June 1962–May 1963

Division of Radiological Health, Public Health Service

The guidance of the Federal Radiation Council (FRC) is given in terms of transient rates of intake of radioactive materials in picocuries per day. The action ranges proposed in FRC Report No. 2 are based on radiation doses considered acceptable for lifetime exposure from normal peacetime atomic industry operations (*1*). The Council recommends the use of a time period of one year as an appropriate interval for averaging exposures and emphasizes that the annual acceptable exposure dose is not a "danger point" which, if exceeded, requires protective measures (*1, 2, 3*).

To facilitate comparison of the concentrations of certain radionuclides in milk with the Radiation Protection Guides, tables 1 and 2 furnish estimates of the contribution of milk to the total dietary intake of iodine–131, strontium–89, and strontium–90. The tables are developed from the PHS Pasteurized Milk Network monthly averages of the radionculides. The index values are estimated sums of the daily amounts of a radionuclide in one liter of milk for a 12-month period.

The tables show 12-month index values for each of the Network's 62 sampling locations. Due to the longer time required for strontium–89 and strontium–90 analysis, these 12-month index values are for the year beginning one month earlier than the iodine–131 values. The columns (B and C) of monthly index values in each table are used to compute the net change as the yearly index values are advanced by one month. Column D shows this new 12-month index value. In addition, the second column in table 1 gives the average iodine–131 concentrations for June 1963.

The data in tables 1 and 2 are calculated as follows: (a) results from all samples collected in each week (Sunday through Saturday) are averaged, (b) the weekly averages for all weeks ending within a given month are averaged and an average for the month is obtained, and (c) the monthly radionuclide index value is determined by multiplying the average for the month by the number of days in the month. The number of days in the month will be either 28 or 35, corresponding to the complete calendar weeks ending in a given month. Procedures exemplified by (a) and (b) above tend to minimize the effect of any one day's sample results on the average for the month, particularly for a short-lived radionuclide such as iodine–131. The yearly index values are obtained by the folowing procedure. Column (A) gives the twelve-month index values for the periods indicated. Columns (B) and (C) show the monthly index values for the periods indicated. The values in column (D) are obtained by adding the values in column (C) to those in column (A) and subtracting those in (B).

For a number of reasons, it is desirable to use a standard quantity of milk in the development of index values for the different radionuclides. When one is concerned with radio-strontium, 1 liter is a suitable quantity, as this amount of milk supplies approximately 1 gram of calcium, the amount used by the Federal Radiation Council in deriving the daily intake guidance for radiostrontium. When one is concerned with iodine–131, the critical age group is the young infant. Available information suggests that the average milk consumption of infants in the 6–18-month group is not more than 1 liter per day (*4, 5*). Thus, the index value based on 1 liter of milk, though not directly an average intake value, is probably the most useful index for estimating total intake.

REFERENCES

(*1*) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2.* Superintendent of Documents, U.S. Government Printing Office (September 1961), price 20 cents.
(*2*) Chadwick, Donald R., and Conrad P. Straub: Considerations in Establishing Radiation Protection Standards for Radioactivity in the Environment, *Radiological Health Data, 3*:159–65, Superintendent of Documents, Government Printing Office, Washington 25, D.C. (May 1962).
(*3*) Public Health Service: Special Report, *Radiological Health Data, 3*:ii–iii, Superintendent of Documents, Government Printing Office, Washington 25, D.C. (September 1962).
(*4*) U.S. Department of Agriculture: *Food, The Yearbook of Agriculture, 1959*, pp. 283–95, Superintendent of Documents, Government Printing Office, Washington 25, D.C. (1959).
(*5*) Public Health Service: Consumption of Selected Food Items in U.S. Households, July 1962. *Radiological Health Data, 4*:124–9, Superintendent of Documents, Government Printing Office, Washington 25, D.C. (March 1963).

TABLE 1.—TWELVE-MONTH SUM OF DAILY AMOUNTS OF IODINE-131 IN ONE LITER OF MILK

[pc day/liter]

Sampling locations		June 1963 iodine-131 averages (pc/liter)	Iodine-131 index values[a]			
			June 1962-May 1963 (A)	May 27-June 30, 1962 (B)	May 26, 1963-June 29, 1963 (C)	July 1962-June 1963 (D)
Ala:	Montgomery	<10	6,170	180	180	6,170
Alaska:	Palmer	<10	38,050	1,050	180	37,180
Ariz:	Phoenix	<10	4,100	350	180	3,930
Ark:	Little Rock	<10	14,420	700	180	13,900
Calif:	Sacramento	<10	4,630	350	180	4,460
	San Francisco	<10	4,630	180	180	4,630
Colo:	Denver	<10	6,100	180	180	6,100
Conn:	Hartford	<10	7,670	350	180	7,500
Del:	Wilmington	<10	11,870	700	180	11,350
D.C:	Washington	<10	8,440	350	180	8,270
Fla:	Tampa	<10	6,660	350	180	6,490
Ga:	Atlanta	<10	8,900	180	180	8,900
Hawaii:	Honolulu	<10	4,590	350	180	4,420
Idaho:	Idaho Falls	<10	9,070	1,050	180	8,200
Ill:	Chicago	<10	12,710	1,050	180	11,840
Ind:	Indianapolis	<10	11,870	1,050	180	11,000
Iowa:	Des Moines	<10	19,290	2,450	180	17,020
Kans:	Wichita	<10	15,720	4,550	180	11,350
Ky:	Louisville	<10	10,120	700	180	9,600
La:	New Orleans	<10	10,190	850	180	10,020
Maine:	Portland	<10	8,160	350	180	7,990
Md:	Baltimore	<10	8,270	180	180	8,270
Mass:	Boston	<10	7,950	350	180	7,780
Mich:	Detroit	<10	12,680	180	180	12,680
	Grand Rapids	<10	9,730	350	180	9,560
Minn:	Minneapolis	<10	12,430	1,050	180	11,560
Miss:	Jackson	<10	9,700	350	180	9,530
Mo:	Kansas City	<10	24,610	8,400	180	16,390
	St. Louis	<10	11,660	2,100	180	9,740
Mont:	Helena	<10	13,970	1,050	180	13,100
Nebr:	Omaha	<10	18,520	2,800	180	15,900
Nev:	Las Vegas[b]	<10	4,870	—[c]	180	5,050
N.H:	Manchester	<10	7,710	180	180	7,710
N.J:	Trenton	<10	7,990	180	180	7,990
N. Mex:	Albuquerque	<10	5,960	180	180	5,960
N.Y:	Buffalo	<10	8,720	350	180	8,550
	New York	<10	11,240	350	180	11,070
	Syracuse	<10	9,730	700	180	9,210
N.C:	Charlotte	<10	3,070	350	180	3,200
N. Dak:	Minot	<10	14,490	700	180	13,970
Ohio:	Cincinnati	<10	14,180	700	180	13,660
	Cleveland	<10	11,100	350	180	10,930
Okla:	Oklahoma City	<10	17,960	5,600	180	12,540
Ore:	Portland	<10	9,770	1,050	180	8,900
Pa:	Philadelphia	<10	10,820	350	180	10,650
	Pittsburgh	<10	14,810	1,050	180	13,940
P.R:	San Juan[d]	<10	5,710	700	180	5,190
R.I:	Providence	<10	8,160	350	180	7,990
S.C:	Charleston	<10	7,180	180	180	7,180
S. Dak:	Rapid City	<10	14,150	180	180	14,150
Tenn:	Chattanooga	<10	7,430	180	180	7,430
	Memphis	<10	10,050	350	180	9,880
Tex:	Austin	<10	11,040	180	180	11,040
	Dallas	<10	18,560	1,050	180	17,690
Utah:	Salt Lake City	10	31,920	350	350	31,920
Vt:	Burlington	<10	8,380	180	180	8,380
Va:	Norfolk	<10	6,270	350	180	6,100
Wash:	Seattle	<10	9,770	350	180	9,600
	Spokane	<10	21,390	12,250	180	9,320
W. Va:	Charleston	<10	6,550	700	180	6,030
Wis:	Milwaukee	<10	14,320	700	180	13,800
Wyo:	Laramie	<10	19,120	700	180	18,600

[a] The data in this table are index values, not to be interpreted as consumption or total intake values. Annual iodine-131 intake per person from milk may be calculated from an index value in this table by applying the appropriate factor representing average individual daily milk consumption for any selected group under consideration.

Example: 12-month I^{131} index × milk consumption factor = 12-month I^{131} intake

(pc day/liter) (liter/day/person) (pc/person)

[b] Station included in network in July 1962. The sum in column A is therefore for 11 months.

[c] A dash indicates no analysis.

[d] No sample was received for November 1962. The sums in columns A and D are therefore for 11 months.

TABLE 2.—TWELVE-MONTH SUM OF DAILY AMOUNTS OF STRONTIUM-89 AND STRONTIUM-90 IN ONE LITER OF MILK

Sampling locations		Strontium-89 index values (pc day/liter)[a]				Strontium-90 index values (pc day/liter)[a]			
		May 1962–Apr. 1963 (A)	May 1962 (B)	Apr. 28, 1963–May 25, 1963 (C)	June 1962–May 1963 (D)	May 1962–Apr. 1963 (A)	May 1962 (B)	Apr. 28, 1963–May 25, 1963 (C)	June 1962–May 1963 (D)
Ala:	Montgomery	21,665	2,520	3,640	22,785	5,838	476	728	6,090
Alaska:	Palmer	19,985	1,120	840	19,705	4,207	224	392	4,375
Ariz:	Phoenix	6,425	280	840	6,985	1,267	56	168	1,379
Ark:	Little Rock	44,905	5,040	6,020	45,885	12,047	1,120	1,428	12,355
Calif:	Sacramento	10,380	840	3,640	13,180	1,848	140	728	2,436
	San Francisco	20,405	1,680	5,600	24,325	2,996	252	700	3,444
Colo:	Denver	11,200	560	560	11,200	4,123	168	336	4,291
Conn:	Hartford	8,070	280	840	8,630	4,214	252	532	4,494
Del:	Wilmington	12,235	1,400	1,820	12,655	5,425	392	868	5,901
D.C:	Washington	13,440	1,400	3,360	15,400	6,041	420	700	6,321
Fla:	Tampa	12,110	700	1,120	12,530	4,165	280	392	4,277
Ga:	Atlanta	27,440	3,220	5,320	29,540	7,287	560	1,008	7,735
Hawaii:	Honolulu	11,305	840	2,100	12,565	2,254	140	280	2,394
Idaho:	Idaho Falls	9,555	420	1,680	10,815	4,039	140	448	4,347
Ill:	Chicago	11,010	840	700	10,870	5,089	336	532	5,285
Ind:	Indianapolis	14,070	1,540	1,960	14,490	5,614	504	980	6,090
Iowa:	Des Moines	25,270	2,520	5,600	28,350	5,530	336	1,148	6,342
Kans:	Wichita	18,270	2,380	1,680	17,570	4,655	308	560	4,907
Ky:	Louisville	29,960	3,080	4,900	31,780	8,204	588	952	8,568
La:	New Orleans	55,440	6,160	4,760	54,040	12,110	952	1,120	12,278
Maine:	Portland	10,800	280	560	11,080	5,964	280	700	6,384
Md:	Baltimore	12,425	1,260	3,360	14,525	5,936	476	728	6,188
Mass:	Boston	11,430	420	840	1,850	6,797	336	644	7,105
Mich:	Detroit	9,995	700	560	9,855	5,117	280	588	5,425
	Grand Rapids	8,770	560	560	8,770	4,305	308	448	4,445
Minn:	Minneapolis	21,000	1,540	1,400	20,860	7,119	308	672	7,483
Miss:	Jackson	52,465	4,900	5,740	53,305	9,744	924	1,064	9,884
Mo:	Kansas City	31,430	3,360	4,760	32,830	5,971	476	1,120	6,615
	St. Louis	20,090	2,800	3,500	20,790	5,285	392	784	5,677
Mont:	Helena	17,395	1,260	1,820	17,955	5,292	308	560	5,544
Nebr:	Omaha	21,280	1,120	3,360	23,520	5,652	224	840	6,268
Nev:	Las Vegas[b]	6,195	—[c]	700	6,895	1,624	—	252	1,876
N.H:	Manchester	10,625	280	840	11,185	5,929	224	672	6,377
N.J:	Trenton	9,715	700	1,120	10,135	4,704	308	700	5,096
N. Mex:	Albuquerque	6,935	280	1,120	7,775	1,806	84	280	2,002
N.Y:	Buffalo	8,980	420	840	9,400	5,026	224	588	5,390
	New York	10,625	560	700	10,765	5,663	392	616	5,387
	Syracuse	9,540	560	700	9,680	4,732	280	588	5,040
N.C:	Charlotte	20,300	1,960	3,920	22,260	8,099	616	896	8,379
N.D:	Minot	18,210	1,680	5,320	21,850	8,610	336	1,568	9,842
Ohio:	Cincinnati	17,325	1,960	2,240	17,605	5,999	532	980	6,447
	Cleveland	10,940	1,260	1,120	10,800	4,921	280	672	5,313
Okla:	Oklahoma City	27,160	3,220	4,620	28,560	7,175	532	840	7,483
Ore:	Portland	33,950	3,780	5,880	36,050	5,733	672	1,344	6,405
Pa:	Philadelphia	10,555	1,120	1,960	11,395	5,446	420	840	5,866
	Pittsburgh	12,480	980	1,260	12,760	6,335	364	616	6,587
P.R:	San Juan[d]	27,335	1,680	2,800	28,455	3,990	224	532	4,298
R.I:	Providence	9,750	560	1,260	10,450	5,215	308	812	5,719
S.C:	Charleston	22,885	2,380	3,920	24,425	7,847	532	784	8,099
S.D:	Rapid City	21,875	280	2,800	24,395	6,363	112	756	7,007
Tenn:	Chattanooga	34,685	4,480	6,580	36,785	8,722	896	1,204	9,030
	Memphis	33,845	3,500	5,320	35,665	8,519	784	1,148	8,883
Tex:	Austin	12,705	840	1,400	13,265	2,898	224	224	2,898
	Dallas	31,465	2,660	3,920	32,725	6,398	560	784	6,622
Utah:	Salt Lake City	12,145	980	840	12,005	4,165	196	532	4,501
Vt:	Burlington	11,045	280	700	11,465	5,124	224	532	5,432
Va:	Norfolk	18,340	1,680	2,660	19,320	7,189	504	728	7,413
Wash:	Seattle	23,625	3,640	5,320	25,305	5,964	672	980	6,272
	Spokane	14,560	2,240	4,480	16,800	5,257	448	1,008	5,817
W. Va:	Charleston	23,135	2,660	5,040	25,515	7,896	560	1,120	8,456
Wis:	Milwaukee	9,015	140	560	9,435	3,689	196	616	4,109
Wyo:	Laramie	20,720	700	1,960	21,980	4,515	168	644	4,991

[a] The data in this table are index values, not to be interpreted as consumption or total intake values. Annual strontium-89 and strontium-90 intake per person from milk may be calculated from an index value in this table by applying the appropriate factor representing average individual daily milk consumption for any selected group under consideration.

Example: 12-month Sr^{89} or Sr^{90} index × milk consumption factor = 12-month Sr^{89} or Sr^{90} intake

(pc day/liter) (liter/day/person) (pc/person)

[b] Station included in network in July 1962. The sum in column A is therefore for 11 months.

[c] A dash indicates no analysis.

[d] No sample was received for November 1962. The sums in columns A and D are therefore for 11 months.

SECTION IV.—WATER

Radioactivity in Raw Surface Waters

NATIONAL WATER QUALITY NETWORK
March 1963

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been under surveillance by the Public Health Service National Water Quality Network since its initiation in 1957. Beginning with the establishment of 50 sampling points, this network has expanded to 126 stations as of August 1, 1963, (figure 1), operated jointly with State, Federal and local agencies and industry. Surface waters of all major river basins of the United States are sampled and analyzed physically, chemically, biologically and radiologically. These data can be used for evaluating sources of radioactivity which may effect specific domestic, commercial, and recreational uses of surface water. Further, the Network provides background information necessary for recognizing pollution and water quality trends and for determining levels of radioactivity to which the population may be subjected. Data assembled through the Network are published in an annual compilation (*1–6*).

FIGURE 1.—TOTAL BETA ACTIVITY (pc/liter) IN SURFACE WATER AT NATIONAL WATER QUALITY NETWORK SAMPLING STATIONS, MARCH 1963

One-liter grab samples are collected weekly by personnel of the participating agencies and shipped to the Public Health Service laboratory in Cincinnati for analysis. Determinations of gross alpha and gross beta radioactivity in the suspended and dissolved solids and of strontium–90 activity in the solids are carried out on frequency schedules based on need.

Gross beta activity in each weekly sample was determined until essentially background levels were reached in January 1960. Thereafter, gross beta determinations were made on monthly composites of the weekly samples received from all stations, except those located downstream from known potential sources of radioactive waste and those from all newly established Network stations. (Weekly alpha and beta measurements are scheduled routinely during the first year of operation at newly established stations.) On September 1, 1961, weekly determinations of gross beta activity again were instituted to permit rapid evaluation of fallout effects from renewed weapons testing. This practice was continued until the end of October 1962, when samples for gross beta analysis were again composited monthly. Gross alpha determinations were made once monthly except where variable or high values observed during the first year indicated the need for more frequent measurement.

Normally, samples are counted at the Network laboratory within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample that shows unusually high activity during the first analysis. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not corrected by extrapolation to the time of collection.

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*7*), Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 microns. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter.

Since the fourth quarter of 1958, strontium–90 analyses have been made on three-month composites of aliquots from weekly samples. Until the fourth quarter of 1961, the method used for determining strontium–90 was that described in the aforementioned reference (*7*). Tributylphosphate was used to extract ingrown yttrium–90 from the purified, coprecipitated strontium–90. Since that time a modification of a procedure described by Harley has been used (*8*). The yttrium–90, together with an yttrium carrier, is precipitated at pH 8.5; the precipitate is washed, re-dissolved, and re-precipitated as yttrium oxalate and the latter is washed and counted in a low-background, anticoincidence, end-window proportional counter.

Table 1 presents March 1963 results of alpha and beta analyses of U.S. raw surface waters. These data are preliminary; reanalysis of some samples may be made and additional analyses, not completed at the time of this report, may become available. For final data one should consult the Network's *Annual Compilation of Data* (*6*). The figures for gross alpha and gross beta radioactivity represent either determinations made on composite samples or means of weekly determinations where composites were not made. The quarterly strontium–90 results for the past year are presented in Table 2.

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS, NWQN, MARCH 1963

[Average concentrations in pc/liter]

Station	Beta activity			Alpha activity			Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total		Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River: Pittsburgh, Pa	51	18	69	1	1	2	Big Horn River: Hardin, Mont	40	34	74	6	2	8
Animas River: Cedar Hill, N. Mex	160	50	210	28	9	37	Big Sioux River: Sioux Falls, S. Dak	76	130	206	1	3	4
Apalachicola River: Chattahoochee, Fla	21	16	37	0	0	0	Chattahoochee River Atlanta, Ga	115	21	136	3	5	8
Arkansas River Coolidge, Kans	38	97	135	4	46	50	Columbus, Ga	35	17	52	1	0	1
Ponca City, Okla	129	88	217	2	11	13	Lanett, Ala	30	16	46	3	0	3
Bear River: Preston, Idaho	15	66	81	0	2	2	Clearwater River: Lewiston, Idaho	11	50	61	0	0	0

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS, NWQN, MARCH 1963—Continued

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Clinch River						
Clinton, Tenn	26	25	51	<1	2	2
Kingston, Tenn	150	132	282	2	1	3
Colorado River						
Loma, Colo	78	54	132	8	6	14
Page, Ariz	6	52	58	<1	11	11
Boulder City, Nev	3	24	27	0	6	6
Parker Dam, Calif-Ariz	1	20	21	0	9	9
Yuma, Ariz	14	121	135	3	0	3
Columbia River						
Northport, Wash	5	18	23	<1	<1	1
Wenatchee, Wash	3	17	20	0	3	3
Pasco, Wash	70	722	792	0	1	1
McNary Dam, Ore	44	322	366	<1	2	2
Bonneville, Ore	40	175	215	0	0	0
Clatskanie, Ore	30	118	148	0	0	0
Cumberland River: Clarksville, Tenn	100	39	139	6	0	6
Connecticut River						
Wilder, Vt	1	81	82	1	1	2
Northfield, Mass	14	24	38	0	0	0
Enfield Dam, Conn	44	37	81	<1	0	<1
Cuyahoga River: Cleveland, Ohio	135	74	209	6	2	8
Delaware River						
Martins Creek, Pa	39	21	60	0	0	0
Trenton, N.J	27	50	77	0	0	0
Philadelphia, Pa	64	39	103	1	0	1
Escambia River: Century, Fla	14	20	34	2	1	3
Great Lakes						
Duluth, Minn	1	10	11	0	0	0
Sault Ste. Marie, Mich	2	10	12	0	0	0
Milwaukee, Wisc	3	11	14	0	0	0
Gary, Ind	5	16	21	0	0	0
Port Huron, Mich	12	13	25	0	0	0
Detroit, Mich	1	15	16	0	0	0
Buffalo, N.Y	1	16	17	0	0	0
Green River: Dutch John, Utah	13	38	51	1	4	5
Hudson River: Poughkeepsie, N.Y	29	28	57	0	0	0
Illinois River						
Peoria, Ill	143	103	246	1	0	1
Grafton, Ill	168	104	272	2	0	2
Kanawha River: Winfield Dam, W. Va	20	33	53	0	5	5
Klamath River: Keno, Ore	28	30	58	1	1	2
Little Miami River: Cincinnati, Ohio	363	85	448	12	0	12
Maumee River: Toledo, Ohio	218	141	359	2	1	3
Merrimack River: Lowell, Mass	21	38	59	0	<1	<1
Mississippi River						
St. Paul, Minn	15	38	53	1	2	3
Dubuque, Iowa	410	188	598	2	0	2
Burlington, Iowa	120	80	200	1	1	2
E. St. Louis, Ill	211	69	280	3	2	5
Cape Girardeau, Mo	150	35	185	10	0	10
W. Memphis, Ark	82	20	102	6	2	8
Vicksburg, Miss	121	39	160	6	<1	6
New Orleans, La	69	25	94	6	0	6
Missouri River						
Williston, N. Dak	22	51	73	2	4	6
Bismarck, N. Dak	14	30	44	0	3	3
Yankton, S. Dak	9	70	79	0	3	3
Omaha, Nebr	303	64	367	7	34	41
St. Joseph, Mo	245	53	298	43	3	46
Kansas City, Kans	106	56	162	20	11	31
Missouri City, Mo	191	58	249	18	4	22
St. Louis, Mo	231	49	280	20	6	26
Monongahela River: Pittsburgh, Pa	96	11	107	4	1	5
North Platte River: Henry, Nebr	14	53	67	<1	28	28
Ohio River						
Addison, Ohio	90	50	140	4	<1	4
Huntington, W. Va	126	27	153	2	0	2
Cincinnati, Ohio	123	30	153	8	0	8
Evansville, Ind	76	15	91	4	0	4
Cairo, Ill	267	36	303	21	0	21
Ouachita River: Bastrop, La	52	56	108	1	1	2
Pend Oreille River: Albeni Falls Dam, Idaho	16	12	28	0	<1	<1
Platte River: Plattsmouth, Nebr	384	154	538	33	6	39
Potomac River						
Williamsport, Md	16	17	33	0	0	0
Great Falls, Md	40	33	73	0	0	0
Rainy River						
Baudette, Minn	7	66	73	0	0	0
International Fls, Minn	3	56	59	0	0	0
Red River, South						
Denison, Tex	2	48	50	0	0	0
Index, Ark	304	101	405	12	1	13
Bossier City, La	131	44	175	3	0	3
Alexandria, La	88	25	113	1	0	1
Rio Grande River						
Alamosa, Colo	10	56	66	0	1	1
El Paso, Tex	175	30	205	0	3	3
Laredo, Tex	8	40	48	1	4	5
Brownsville, Tex	5	15	20	0	1	1
Roanoke River: John H. Kerr Resr. & Dam, Va	35	23	58	1	0	1
Sabine River: Ruliff, Tex	37	36	73	1	0	1
Sacramento River: Green's Landing, above Courtland, Calif	14	15	29	1	1	2
San Joaquin River: Vernalis, Calif	12	26	38	1	3	4
San Juan River: Shiprock, N. Mex	40	52	92	5	23	28
St. Lawrence River: Massena, N.Y	1	15	16	0	0	0
Schuylkill River: Philadelphia, Pa	144	90	234	1	0	1
Savannah River						
North Augusta, Ga	18	12	30	0	0	0
Port Wentworth Ga	19	24	43	1	0	1
Shenandoah River: Berryville, Va	23	103	126	0	7	7
Ship Creek: Anchorage, Alaska	7	26	33	0	<1	<1
Snake River						
Ice Harbor Dam, Wash	10	22	32	0	1	1
Wawawai, Wash	19	22	41	1	0	1
Payette, Idaho	9	34	43	0	0	0
South Platte River: Julesburg, Colo	44	66	110	2	44	46
Spokane River: Post Falls, Idaho	8	14	22	<1	0	<1
Susquehanna River						
Syre, Pa	45	23	68	1	0	1
Conowingo, Md	23	15	38	0	0	0
Tennessee River						
Lenoir City, Tenn	48	20	68	2	1	3
Chattanooga, Tenn	238	48	286	12	1	13
Bridgeport, Ala	85	41	126	4	0	4
Pickwick Landing, Tenn	50	28	78	0	1	1
Tombigbee River: Columbus, Miss	83	35	118	2	1	3
Truckee River: Farad, Calif	4	42	46	1	0	1
Verdigris River: Nowata, Okla	124	53	177	12	3	15
Wabash River: New Harmony, Ind	191	105	296	2	1	3
Willamette River: Portland, Ore	24	12	36	1	1	2
Yakima River: Richland, Wash	5	10	15	0	1	1
Yellowstone River: Sidney, Mont	80	44	124	13	2	15
Maximum	410	722	792	43	46	46
Minimum	1	10	11	0	0	0

TABLE 2.—QUARTERLY STATION AVERAGE CONCENTRATIONS OF STRONTIUM-90 IN RAW SURFACE WATERS, APRIL 1962–MARCH 1963

(Concentrations in pc/liter)

Station	Second quarter 1962	Third quarter 1962	Fourth quarter 1962	First quarter 1963
Allegheny River: Pittsburgh, Pa	1.2	2.1	1.8	[a]—
Animas River: Cedar Hill, N. Mex	1.0	0.4	0.9	—
Apalachicola River: Chattahoochie, Fla	0.9	0.4	0.4	—
Arkansas River				
Coolidge, Kans	3.9	2.6	1.0	—
Ponca City, Okla	3.0	4.8	2.2	—
Bear River: Preston, Idaho	—	[b]1.3	0.9	—
Big Horn River: Hardin, Mont	6.4	3.7	1.3	—
Big Sioux River: Sioux Falls, S. Dak	5.9	5.4	2.5	—
Chattahoochie River				3.6
Atlanta, Ga	0.8	0.7	1.0	—
Columbus, Ga	—	[c]0.8	1.1	—
Lanett, Ala	—	1.5	0.8	—
Chena Slough: Fairbanks, Alaska	[c]1.4	0.4	0.3	—
Clearwater River: Lewiston, Idaho	0.4	0.5	0.4	—
Clinch River				
Clinton, Tenn	—	1.3	1.0	
Kingston, Tenn	1.7	12.6	—	6.3
Colorado River				
Yuma, Ariz	1.0	1.2	0.9	—
Parker Dam, Ariz.-Calif	1.7	1.7	1.3	—
Boulder City, Nev	2.0	1.7	1.5	—
Page, Ariz	4.9	1.5	6.9	1.5
Loma, Colo	1.5	0.8	0.5	—
Columbia River				
Clatskanie, Ore	0.7	0.6	0.9	—
Bonneville Dam, Ore	1.6	0.4	1.2	1.4
McNary Dam, Ore	0.7	1.4	1.0	—
Wenatchee, Wash	0.8	1.2	1.6	2.3
Pasco, Wash	0.8	1.8	1.5	—
Northport, Wash	0.6	1.3	0.9	—
Connecticut River				
Northfield, Mass	1.0	1.3	1.0	—
Enfield Dam, Conn	1.0	1.4	1.0	—
Wilder, Vt	0.8	1.4	0.9	—
Cuyahoga River: Cleveland, Ohio	—	—	—	1.4
Delaware River				
Philadelphia, Pa	1.3	1.6	2.4	—
Trenton, N.J	1.6	1.5	0.9	—
Martins Creek, Pa	1.1	0.5	1.2	—
Escambia River: Century, Fla	1.1	1.0	—	—
Great Lakes				
Lake Superior: Duluth, Minn	0.5	0.7	0.7	—
St. Marys River: Sault Ste. Marie, Mich	0.6	0.9	0.8	—
Lake Michigan: Milwaukee, Wis	0.7	0.9	0.8	—
St. Clair River: Port Huron, Mich	1.3	1.0	0.8	—
Lake Erie: Buffalo, N.Y	1.1	1.3	1.7	—
Detroit River: Detroit, Mich	1.2	1.5	1.1	—
Lake Michigan: Gary, Ind	0.7	1.0	0.7	—
Green River: Dutch John, Utah	—	1.9	1.2	—
Hudson River: Poughkeepsie, N.Y	1.7	1.7	3.0	—
Illinois River				
Pere Marquette State Park, Grafton, Ill	2.4	1.4	1.8	—
Peoria, Ill	1.7	—	1.7	—
Kanawha River: Winfield Dam, W. Va	0.8	1.3	1.1	—
Klamath River: Keno, Ore	1.3	2.8	0.9	—
Little Miami River: Cincinnati, Ohio	2.9	0.9	1.6	—
Maumee River: Toledo, Ohio	—	—	—	3.6
Merrimac River: Lowell, Mass	—	—	0.9	—
Mississippi River				
New Orleans, La	2.3	2.1	1.9	—
Vicksburg, Miss	3.1	2.0	2.0	—
Delta, La	1.9	1.1	2.1	—
W. Memphis, Ark	2.7	2.4	2.0	—
Cape Girardeau, Mo	2.8	3.1	2.7	—
East St. Louis, Ill	2.2	2.7	1.8	—
Burlington, Iowa	2.0	2.1	2.1	—
Dubuque, Iowa	2.9	—	2.6	—
Lock & Dam, #3, St. Paul, Minn	3.9	4.7	3.4	—
Missouri River				
St. Louis, Mo	2.7	2.5	2.7	—
Missouri City	2.8	2.2	2.6	—
Kansas City, Kans	1.8	3.4	3.4	—
St. Joseph, Mo	3.0	5.7	1.9	—
Omaha, Nebr	4.2	3.8	2.5	—
Yankton, S. Dak	2.3	2.3	2.3	—
Bismarck, N. Dak	1.9	1.4	1.7	—
Williston, N. Dak	1.1	3.0	1.5	—
Monongahela River: Pittsburgh, Pa	0.9	1.8	1.5	—
North Platte River: Henry, Nebr	2.2	2.1	0.6	—
Ohio River				
Cairo, Ill	2.0	1.4	1.7	—
Evansville, Ind	1.4	1.3	1.6	—
Louisville, Ky	1.3	3.3	1.4	—
Cincinnati, Ohio	1.9	1.5	1.6	—
Huntington, W. Va	1.9	1.5	1.6	—
Addison, Ohio	—	1.3	2.1	—
E. Liverpool, Ohio	1.5	—	—	—
Ouachita River: Bastrop, La	1.6	1.0	1.6	—
Pend Oreille River: Albeni Falls Dam, Idaho	1.6	0.5	0.7	—
Platte River: Plattsmouth, Nebr	6.0	4.1	2.3	—
Potomac River				
Great Falls, Md	2.2	1.2	1.0	—
Williamsport, Md	0.9	1.2	1.6	—
Rainy River				
International Falls, Minn	2.4	1.4	1.8	—
Baudette, Minn	1.4	1.7	2.2	—
Red River (South)				
Alexandria, La	2.5	2.0	3.9	—
Bossier City, La	—	2.2	2.0	—
Index, Ark	6.1	—	3.3	—
Denison, Tex	2.2	1.1	5.0	—
Rio Grande River				
Brownsville, Tex	1.2	0.7	1.3	—
Laredo, Tex	2.0	1.8	1.8	—
El Paso, Tex	1.2	1.7	0.7	—
Alamosa, Colo	1.1	0.5	0.5	—
Roanoke River: John H. Kerr Resr. & Dam Va	2.5	1.8	1.1	—
Sabine River: Ruliff, Tex	1.7	1.0	1.4	—
Sacramento River: Greens Landing, Calif	0.9	0.8	0.9	—
St. Lawrence River: Massena, NY	1.2	0.3	1.2	—
San Joaquin River: Vernalis, Calif	—	0.7	1.0	—
San Juan River: Shiprock, N. Mex	1.0	1.0	1.7	—
Savannah River				
Port Wentworth, Ga	1.9	2.2	0.6	2.4
North Augusta, S.C	1.0	0.8	0.6	—
Schuylkill River: Philadelphia, Pa	1.5	1.8	1.3	—
Shenandoah River: Berryville, Va	0.9	0.4	0.8	—
Ship Creek: Anchorage, Alaska	[c]0.2	—	0.3	—
Snake River				
Ice Harbor Dam, Wash	0.9	1.1	1.6	—
Wawawai, Wash	0.6	0.9	0.7	—
Payette, Idaho	0.6	1.1	0.8	—
South Platte River: Julesburg, Colo	1.7	2.2	0.8	—
Spokane River: Post Falls, Idaho	0.7	0.9	0.8	—
Susquehanna River				
Conowingo, Md	1.0	2.1	1.2	—
Sayre, Pa	1.2	1.0	1.0	—
Tennessee River				
Pickwick Landing Dam, Tenn	1.7	1.1	1.4	—
Bridgeport, Ala	2.0	0.6	1.0	—
Chattanooga, Tenn	1.6	1.2	1.4	2.6
Lenoir City, Tenn	1.1	2.8	1.0	—
Tombigbee River: Columbus, Miss	1.4	1.6	0.6	—
Truckee River: California-Nevada Border: Farad, Calif	0.9	0.7	0.9	—
Verdigris River: Nowata, Okla	3.1	2.3	2.5	—
Wabash River: New Harmony, Ind	4.7	2.0	1.4	—
Willamette River: Portland, Wash	—	0.5	0.6	—
Yakima River: Richland, Wash	0.4	0.3	0.7	—
Yellowstone River: Sidney, Mont	3.0	1.5	2.0	—
Maximum	6.4	12.6	6.9	6.3
Minimum	0.2	0.3	0.3	0.4

[a] Dash indicates no data received.
[b] Aug.-Sept. composite.
[c] Six months composite.

In order to obtain a geographical perspective of the radioactivity in surface water, the numbers alongside the various stations in figure 1 give the total beta activity in suspended-plus-dissolved-solids in raw water collected at that station. Network results for the years 1957–1962 have been summarized by Weaver *et al* (*9*).

REFERENCES

(*1*) Division of Water Supply and Pollution Control, Public Health Service: *National Water Quality Network Annual Compilation of Data*, PHS Publication No. 663, 1958 Edition, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

(*2*) Ibid., 1959 Edition.

(*3*) Ibid., 1960 Edition.

(*4*) Ibid., 1961 Edition.

(*5*) Ibid., 1962 Edition (in press).

(*6*) Ibid., 1963 Edition (to be published).

(*7*) American Public Health Association, American Water Works Association and Water Pollution Control Federation: *Standard Methods for the Examination of Water and Wastewater*, 11th Edition, New York (1960).

(*8*) Harley, J. H.: Radiochemical Determination of Strontium–90, *Health and Safety Laboratory Manual of Standard Procedures*, August 1962 Revision, Radiochemistry and Environmental Studies Division, U.S. Atomic Energy Commission, New York Operations Office (1962).

(*9*) Weaver, L., A. W. Hoadley, and S. Baker: Radioactivity in Surface Waters of the United States, 1957–1962, *Radiological Health Data*, 4:306–16, Superintendent of Documents, Government Printing Office, Washington 25, D.C. (June 1963).

RADIOACTIVITY IN CALIFORNIA SURFACE WATER[1]

July–December 1962

Bureau of Radiological Health
State of California, Department of Public Welfare

Results obtained by the Bureau of Radiological Health in its monitoring of California surface water during the period July to December 1962 are summarized below. The importance of this facet of the Bureau's environmental surveillance program stems from the fact that most of California's domestic water supplies come from surface sources. Radioactivity in such water supplies consists of the natural radioactivity in surface streams and any radioactivity that may be added by the discharge of sewage or industrial waste effluents into streams. These water supplies may also contain radioactivity from fallout, particularly fallout into open terminal or distribution reservoirs. Most of the supplies sampled represent raw surface waters although a few wells, along with some water supplies that use infiltration galleries, are also sampled (see figure 1).

It is necessary to monitor domestic water supplies on a continuous basis, since it is impossible to forecast levels of radioactivity in these supplies on the basis of radioactivity in rain, snow, or surface streams. The Bureau has established a monthly sampling schedule whereby 500-ml samples are collected and the total solids are analyzed for alpha and beta radioactivity. In addition, a three-liter sample is collected each month for a period of six months to make up a composite of approximately five gallons for strontium–90 analysis.

FIGURE 1.—CALIFORNIA SURFACE WATER SAMPLING STATIONS

[1] Abstracted from "Radiological Health News," Vol 2, No. 1 and 2, Jan. and April 1963, State of California, Department of Public Health, Bureau of Radiological Health, 2151 Berkeley Way, Berkeley 4, California.

Laboratory Methods

Radiological analysis of water samples are carried out in the Sanitation and Radiation Laboratory. All measurements of alpha and alpha-plus-beta activities are made with windowless, gas-flow, proportional counters. Five proportional counters, four of which are manual counters, are available to the Bureau. Two of the manual units have specially designed, shielded external detectors which reduce the alpha and beta backgrounds to 0.01 and 30 cpm, respectively. In the case of the two integrally constructed manual units the relatively high beta background has been reduced to 40 cpm by partial shielding of the scaler with lead bricks. The fifth counter is an automatic unit which has a beta backgound of about 15 cpm.

The Department's maximum capacity for alpha and beta radioactivity measurements during a normal work week is 500 thirty-minute counts. Counting methods used are in accordance with U.S. Public Health Service's recommended procedures (*1*).

Discussion

Table 3 shows the monthly average beta activity in the suspended-plus-the-dissolved solids in raw

TABLE 3.—GROSS BETA ACTIVITY IN CALIFORNIA SURFACE WATER, JULY–DECEMBER 1962

[Concentrations in pc/liter]

Sampling station	July	Aug.	Sept.	Oct.	Nov.	Dec.
Antioch	17.6	9.2	14.4	31.0	[a]0	27.7
Chula Vista	10.7	[b]				
Clearlake Highlands	14.8			30.3	0	26.3
Crescent City	7.3	4.8	0	0	0	24.3
Dos Palos	0					
Escondido	34.1	10.1	0	0	33.6	0
Eureka	[c]6.6	1.9	15.4	45.3	0	24.7
Fort Bragg			12.4	74.9	61.8	0
Fresno: Lake Millerton	[c]20.9	[c]25.4	[c]23.7	[c]14.1	0	0
Los Angeles Department of Water and Power						
Big Tujunga				0		
Crystal Springs Wells				0		
Pollack Wells				0		
Marin Municipal Water District Nicasio Reservoir		9.1	0	0	0	0
Mariposa		17.2	0	0	49.3	0
Metropolitan Water Company of Southern California						
Lake Havasau		12.7	18.0	0	0	0
Lake Mathews	19.8	0	12.1	0	0	0
Monterey	0.6	10.7	1.3	25.1	0	45.1
Napa	8.8	8.6	5.0	0	0	0
North Marin County Water District	2.0	11.7	0	0	0	0
Oroville						
Wyandotte Irrigation District	9.9	32.0		30.7		63.3
California Water Service	1.9		4.7		0	
Placerville			24.5	0		
Redding	0	0	15.3	26.5	0	62.8
Sacramento	7.6	0		0	0	0
San Diego						
Alvarado Filter Plant	0	7.5	20.5			
El Capitan Reservoir		0				
First Aqueduct		22.3				
Hodges Reservoir		26.1				
Lower Otay Filter Plant		28.7		0		
Murray Reservoir	0			0		
San Dieguito Reservoir		0		0		
San Vicente		0				
Second Aqueduct						
Sutherland Reservoir		14.7				
Torrey Pines Reservoir		5.8				
San Francisco Water Department						
Alameda East	69.0	17.2	17.2	32.2	31.5	0
Brightside Weir	26.4	14.0		0	0	0
Calaveras Reservoir	3.6	3.5	1.5	0	0	0
Crystal Springs Raw Outlet	13.3	21.2	[a]0	0	0	0
Crystal Springs Line #1	[c]12.3	[c]4.0	[c]16.0	[c]11.0	[c]14.0	[a]0
Crystal Springs Line #2	0.1		4.4			
Hetch Hetchy	46.1	0.5	0	0	0	56.7
Lombard Reservoir	3.9	0	15.1	0	0	0
San Andreas Line #2	[c]7.6	[c]8.5	[c]6.2			[a]0
San Andreas Line #3				[a]0	[a]0	
University Mound	20.3	21.7	0	0	0	0
San Jose	34.5	4.2	1.1	0	0	0
San Luis Obispo	15.0					
Santa Barbara	2.7	4.0	14.2	0	50.5	0
Santa Cruz	[c]13.1	13.2	3.5	0	27.5	44.4
Santa Rosa		60.2	4.9	0	0	59.0
Scotia		0	0		0	0
Tahoe City	0	0	13.4	0		
Vallejo						
Fleming Hill	0	4.8	22.2	31.4	31.5	54.0
Swanzy Reservoir	8.9	10.2	0	0	0	28.2
Vista	32.1	25.1				0
Willits	27.5	26.3	7.1	0	0	40.0
Yosemite	17.2	18.3	0	45.0	0	30.8

[a] No significant activity.
[b] Blank space indicates no sample collected or analyzed.
[c] Average of more than one sample for the month.

surface water in California from July 1962 through December 1962. Following treatment, these waters are used for industrial and domestic purposes. Because alpha activity in water has, in general, been undetectable or very slight, alpha activity analyses are not presented.

REFERENCE

(1) Public Health Service: *Radionuclide Analysis of Environmental Samples.* Nov. 16, 1959, R59–6, Robert A. Taft Sanitary Engineering Center, Superintendent of Documents, U.S. Government Printing Office, Washington, 25-D.C. (1959).

Previous coverage in *Radiological Health Data:*

Period	*Issue*
1961–June 1962	*April 1963*

SECTION V.—OTHER DATA

In Vivo Measurement of Iodine—131 in Children's Thyroids

Francis I. Visalli[1]

Iodine–131 in the thyroids of a group of children was measured by *in vivo* counting at the Northeastern Radiological Health Laboratory from May to November 1962, a period covering a large part of the nuclear weapons testing series of both the United States and the U.S.S.R. During most of this period, little or no fallout radioiodine reached the greater Boston area so that no significant measurements could be made until about the middle of September. The iodine–131 measured was that present in the children as a result of normal environmental exposure during a fallout period. No radioiodine was administered to the children, nor did any child receive more radiation than he would have if he had not participated in the study. The iodine–131 contents of the thyroids of these children are presented in table 1.

Method of Measurement

Gamma scintillation spectroscopy was the method of measurement used. Measurements were made inside a small, shielded octagonal room with inside dimensions of approximately 43 inches across by 55 inches high. The walls of the room were 2⅛-inch thick iron plates lined on the inside with ¼ inch of lead plus 1/16 inch of cadmium. A child being measured was placed in a semi-reclining position with his head tilted back to allow a 2.5-inch diameter x 1.5-inch thick, thallium-activated sodium iodide crystal to be placed over each lobe of the thyroid, as shown in figure 1. Because of the dimensions of the shielded room and the necessity of having having a child sit still for about 30 minutes, the study was limited to children from 7 to 14 years of age. Each child had his thyroid counted for 30 minutes twice a week. The measurement data were accumulated in a multichannel analyzer, using the region from 0.33 to 0.39 Mev as the iodine–131 peak.

The system was calibrated with iodine–131 in vials approximating the positions of the lobes of the thyroid in a lucite neck phantom. In order to simulate the scattering characteristics of the child, five 10-pound bags of sugar were used as a body phantom. In addition to these simulated calibrations, two adults who had been exposed to iodine–131 were measured with the Northeastern Radiological Health Laboratory equipment and were also measured in the whole body counter at New York University, which had previously been used for such measurements (*1*). The results of these cross calibrations were in agreement.

[1] Miss Visalli is in charge of the iodine–131 thyroid studies at the Northeastern Radiological Health Laboratory, Division of Radiological Health, Public Health Service, 109 Holton Street, Winchester, Massachusetts.

TABLE 1.—IODINE-131 IN CHILDREN'S THYROIDS AND IN MILK, SEPTEMBER-NOVEMBER 1962

Date 1962	Iodine-131 in children's thyroids (pc/gland)								Milk[a] (Concentrations in pc/liter)
	Subject (age)								
	LG (7)	ES (7)	MP (10)	TT (10)	GRM (11)	BM (12)	DG (13)	SB (14)	
September 18					<30				10
19			<30	<30					
20	<30						<30	<30	
21		140							140
22									
23									
24						<30			
25					<30				210
26			<30	60					
27	<30						<30	<30	
28		100							170
29					<30				
30									
October 1		155				150	80		
2	40		150	115				125	130
3					170				
4		215				45	105		
5	90		135	65				160	100
6									
7					150				
8		195				135			
9	40		75					90	
10					120				80
11		225				75	60		70
12	<30		125	125				80	
13									
14					95				
15						95	<30		
16	<30		75	60				55	70
17					120				
18		110				105	45		
19			40	55					80
20									
21									
22		190				75			
23			65	115					70
24									
25		160				115			
26			50						90
27									
28									
29		145				55			
30									90
31									
November 1						180			
2									50
3									
4									
5		210				110			
6			70	120					50
7									[b]40
8		190				120			
9			85	120					40
10									
11									
12									
13						100			40
14									
15									70
16						60			
17									
18									90
19									
20						90			50

[a] Boston station of the PHS Pasteurized Milk Network.
[b] Actual milk consumed after November 7, 1962—not identical with Boston network sample.

FIGURE 1.—SHIELDED ROOM WITH DOOR OPEN, SHOWING POSITION OF CRYSTALS AND CHILD DURING MEASUREMENT

Discussion of Results

With the equipment used, the estimated minimum detectable level of iodine–131 in the thyroid, defined as the level below which the random statistical error is greater than the measurement, is approximately 30 picocuries; therefore nondetectable results were reported as "less than 30 pc." The precision (reproducibility) of the thyroid measurements at relatively low levels is estimated to be ± about 30 pc; at higher levels the deviation is somewhat greater than this, but is probably not more than ± 50 pc at the highest level. These errors are at the 90 percent level of confidence (1.64 standard deviations). Accuracy of the measurements, because of the uncertainty as to the position of the thyroid in the neck, is not as good as this.

Since the reported measurements are limited to eight children, it is not possible to draw broad conclusions as to the range of the radioiodine content of childrens' thyroids in the entire population of the Boston area. It is significant, however, that no radioiodine was detectable in the children from May to mid-September of 1962, a period in which dietary radioiodine levels, as indicated by measurements in milk, were low. The rise in thyroid radioactivity followed very shortly the appearance of iodine–131 in Boston milk samples, and reached a peak value about ten to fourteen days after peak levels in milk were observed There was no apparent correlation between the levels of radioiodine in the children and the gross beta measurements in air (*2*), suggesting that diet is the chief source of thyroid iodine–131.

It was not possible to relate the concentration of iodine–131 in the childrens' thyroids directly to the levels in milk or to the intake from milk. The childrens' homes were served by different dairies and most of them also drank milk provided through several school milk programs. In addition, they consumed variable quantities of ice cream and other dairy products of unknown origin and also an unknown quantity of milk used in cooking.

An attempt to relate directly milk ingestion values to thyroid content was made during the last two weeks reported. A single source of milk from one of the larger Boston dairies was provided for all the children, and they were asked to report the amount used. Because the milk levels were rather low, and the children had previously established thyroid burdens, possible correlation could not be further considered. The iodine–131 content of this dairy's milk was found to be approximately the same as the composite Boston Milk Sample for the same period, so it may be taken as a first approximation that the levels in the composite of the Boston Milk Sample are an indication of the levels in the milk and other foods consumed by the children.

REFERENCES

(*1*) Eisenbud, Merrill, Yoshio Mochizuki, Abraham S. Goldin, and Gerard R. Laurer: Iodine–131 Dose From Soviet Nuclear Tests, *Science, 136:* 370–4 (May 4, 1962)
(*2*) Unpublished data, Northeastern Radiological Health Laboratory and Radiation Surveillance Center, Public Health Service.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors quarterly reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports included data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 22 AEC installations have appeared periodically in *Radiological Health Data* since November 1960. Summaries follow for Oak Ridge Area, and Paducah Plant.

The measured concentration of a radionuclide in air and water may be compared with the Maximum Permissible Concentration (MPC) of that nuclide as recommended by the National Committee on Radiation Protection and Measurement (NCRP). For the environment near an AEC installation, the applicable MPC's are one-tenth of the occupational MPC values for continuous exposures given in the National Bureau of Standards "Handbook 69" (*1*). The MPC values applicable to the reports that follow are given in table 1.

In the following reports, the use of nonspecific terms such as "total activity," "total alpha," and "gross beta" do not in themselves suggest any one MPC value. Often, when concentrations are low a laboratory will assign an MPC value that is more restrictive than necessary. This avoids the more costly isotopic tests necessary to justify a less restrictive value. References to table 1 will be made to designate the appropriate MPC's reported by the laboratories.

TABLE 1.—SELECTED ENVIRONMENTAL MPC VALUES PERTAINING TO AEC INSTALLATION REPORTS IN THIS SUBSECTION

Line No.	Radionuclide or mixture of unknown nuclides	Environmental MPC's	
		Water (pc/liter)	Air (pc/m³)
1	If Sr^{90}, I^{129}, Pb^{210}, Po^{210}, At^{211}, Ra^{223}, Ra^{224}, Ra^{226}, Ac^{227}, Ra^{228}, Th^{230}, Pa^{231}, Th^{232}, and Th-nat are not present[a]	3,000	—
2	If Sr^{90}, Pb^{210}, Ra^{226}, Ra^{228} are not present[a]	600	—
3	If Ra^{226}, Ra^{228} are not present[a]	100	—
4	Mixture of unidentified nuclides	10	0.04
5	If α emitters and Ac^{227} are not present[a]	—	1.0
6	If α emitters and Pb^{210}, Ac^{227}, Ra^{227}, Pu^{241} are not present[a]	—	10
7	If α emitters and Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, Bk^{249} are not present[a]	—	100
8	Cerium–144	10,000	200
9	Cesium–137	20,000	500
10	Cobalt–60	30,000	300
11	Ruthenium–103–106	10,000	200
12	Strontium–90	100	10
13	Thorium-protactinium–234	20,000	1000
14	Uranium-natural	20,000	2
15	Zirconium-niobium–95	60,000	1000

[a] "Not present" implies the concentration of the nuclide is small compared with its appropriate MPC. According to AEC regulations, a group of nuclides may be considered not present if the ratio of each nuclide is equal to or less than $^1/_{10}$ of its appropriate MPC and if the sum of these ratios for the group in question is equal to or less than ¼.

REFERENCE

(*1*) National Committee on Radiation Protection: *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure, National Bureau of Standards Handbook 69*, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (June 5, 1959), price 35 cents.

OAK RIDGE AREA
Calendar Year 1962

Union Carbide Nuclear Company
Oak Ridge, Tennessee

This report presents 1962 data on the environmental levels of radioactivity for the Oak Ridge Area. As shown in figure 1, K–25, X–10 and Y–12 areas are located within the large AEC-controlled Oak Ridge Area. The Oak Ridge National Laboratory (ORNL) is located within the X–10 area and the Oak Ridge Gaseous Diffusion Plant (ORGDP) is located within the K–25 area.

Radioactive waste materials arising from the operation of atomic energy installations in Oak Ridge area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ion exchange activity that enables it to fix radioactive materials. Liquid wastes which contain long-lived fission products are confined in storage tanks or are released to trenches and pits located in the Conasauga shale formation. Low level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

Air Monitoring

Atmospheric contamination by long-lived fission products and fallout occurring in the general environment of East Tennessee are monitored by

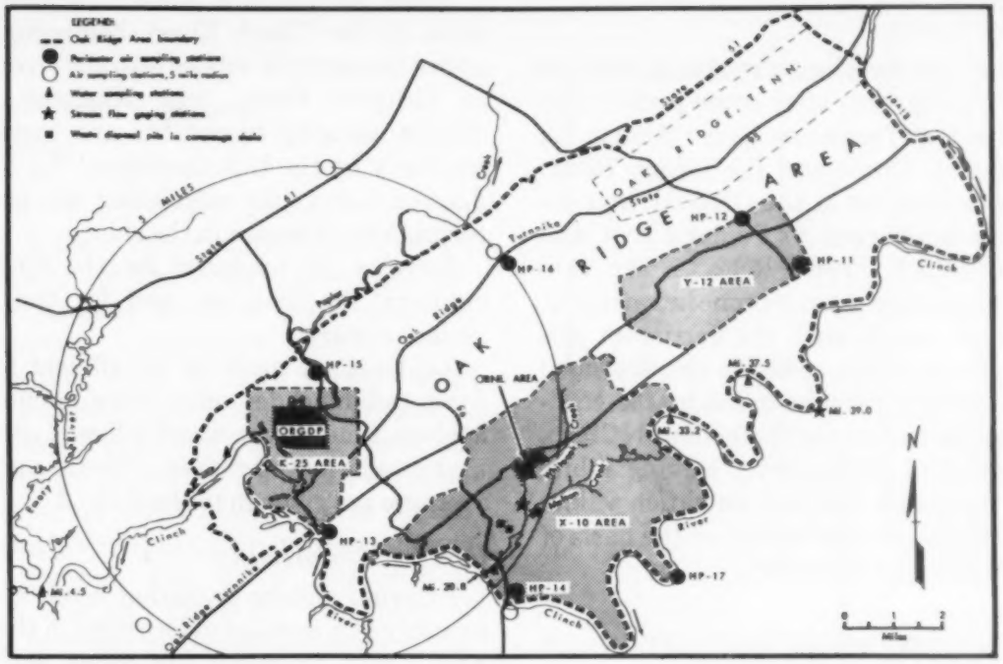

FIGURE 1.—OAK RIDGE AREA ENVIRONMENTAL SAMPLING LOCATIONS

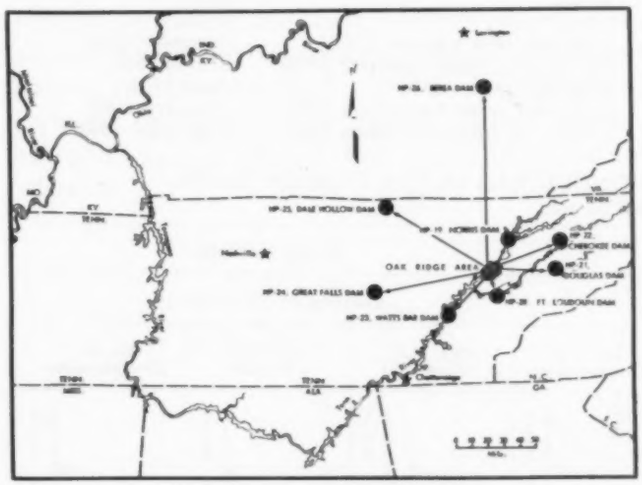

FIGURE 2.—REMOTE AIR MONITORING STATIONS, OAK RIDGE AREA

two systems of monitoring stations. One system consists of seven stations which encircle the plant areas (figure 1) and provide data for evaluating the impact of all Oak Ridge Operations on the immediate environment. A second system consists of seven stations encircling the Oak Ridge Area at distances of from 12 to 75 miles (figure 2). This system provides data to aid in evaluating local conditions and to assist in determining the spread or dispersal of contamination should a major incident occur. Sampling is carried out by passing air continuously through a filter paper. Average concentrations are presented in table 2.

Atmospheric contamination by uranium is determined by gross alpha measurements of continuous air samples taken at five locations on a five-mile radius from the ORGDP (figure 1). The data are summarized in table 3.

TABLE 2.—LONG-LIVED GROSS BETA[1] CONCENTRATIONS IN AIR OAK RIDGE AREA, 1962

[Average concentrations in pc/m³]

Perimeter stations: (see fig. 1 & 2)	First half 1962	Second half 1962	Remote stations: (see fig. 1 & 2)	First half 1962	Second half 1962
HP-11	3.8	2.9	HP-19	5.2	3.5
HP-12	4.1	3.3	HP-20	4.7	3.8
HP-13	3.8	2.7	HP-21	5.2	3.6
HP-14	3.9	2.9	HP-22	4.5	3.6
HP-15	4.6	3.3	HP-23	5.0	3.9
HP-16	4.3	3.4	HP-24	5.1	4.0
HP-17	4.1	2.8	HP-25	4.5	3.2
Average	4.1	3.0	Average	4.9	3.6

[1] For MPC, see table 1, line 7.

Water Monitoring

Large volume, low level liquid wastes originating at ORNL are discharged, after some preliminary treatment, into the Tennessee River System by way of White Oak Creek and the Clinch River. Liquid wastes originating at the ORGDP and the Y–12 Plant are discharged to Poplar Creek and thence to the Clinch River. Releases are controlled so that resulting average concentrations in the Clinch River comply with the maximum permissible levels for populations in the neighborhood of a controlled area as recommended by the National Committee on Radiation Protection (NCRP). The concentration of radioactivity leaving White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

TABLE 3.—LONG-LIVED ALPHA[1] ACTIVITY IN AIR FIVE MILES FROM ORGDP

[Average concentrations in pc/m³]

Direction from plant	First half 1962	Second half 1962
North	0.17	0.28
East	0.16	0.36
South	0.17	0.30
West	0.16	0.46
Average	0.16	0.33

[1] Interpreted as uranium (natural).

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tennessee. Stream gauging operations are carried on continuously by the U.S. Geological Survey to obtain dilution factors for calculating the probable concentrations of wastes in the river.

Samples are analyzed for the long-lived beta emitters, for uranium, and for the transuranic alpha emitters.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold-up time in the waste effluent system is such that no short-lived radionuclides are present. The averages are given in tables 4 and 5.

Gamma Measurements

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge Area. Measurements are taken with a Geiger-Mueller tube at a distance of 3 feet above ground, and the results are shown in table 6 in terms of mr/hr.

Previous coverage in *Radiological Health Data:*

Period	*Issue*
1959 and first quarter 1960	*December 1960*
Second and third quarters 1960	*March 1961*
Fourth quarter 1960	*July 1961*
First and second quarters 1961	*January 1962*
Third and fourth quarters 1961	*September 1962*

TABLE 4.—CONCENTRATIONS OF MAJOR RADIONUCLIDES IN THE CLINCH RIVER

[Average concentrations in pc/liter]

Radionuclide	First half 1962			Second half 1962		
	Location on Clinch River[a]			Location on Clinch River[a]		
	Mi. 41.5 (Upstream)	Mi. 20.8[b] (Outfall)	Mi. 4.5 (Downstream)	Mi. 41.5 (Upstream)	Mi. 20.8[b] (Outfall)	Mi. 4.5 (Downstream)
Sr^{90}	2.0	2.2	4.1	1.1	1.4	2.8
Ce^{144}	1.7	0.3	2.7	1.0	0.2	2.3
Cs^{137}	0.1	1.2	1.2	0.2	0.9	0.1
$Ru^{103-106}$	9	180	210	7	94	110
Co^{60}	[c]ND	2.4	4.1	ND	1.8	1.8
Zr^{95} – Nb^{95}	6.8	2.4	7.4	1.6	0.2	3.4
Gross beta	20	390	230	11	290	120

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River. See figure 1.
[b] The concentrations at mi. 20.8 are not measured directly but the values are calculated on the basis of levels of waste released and the dilution afforded by the river.
[c] ND—None detected.

TABLE 5.—URANIUM CONCENTRATIONS IN THE CLINCH RIVER, OAK RIDGE AREA

[Average concentrations in pc/liter]

Sampling location	First half 1962		Second half 1962	
	Number of samples	Uranium concentration	Number of samples	Uranium concentration
Upstream from ORGDP	27	0.2	25	1
Downstream from ORGDP	27	0.2	26	4

TABLE 6.—EXTERNAL GAMMA RADIATION LEVELS, OAK RIDGE AREA

[Average dose rates in mr/hr]

Location	First half 1962	Second half 1962
Solway Gate	0.030	0.036
Y-12 East Portal	0.021	0.030
Newcomb Road	0.027	0.028
Gallaher Gate	0.034	0.038
White Wing Gate	0.021	0.023
Average	0.027	0.031

PADUCAH PLANT
Calendar Year 1962

Union Carbide Nuclear Company
Paducah, Kentucky

The Paducah Plant is a Government-owned gaseous diffusion plant operated by Union Carbide Nuclear Company for the Atomic Energy Commission. The gaseous diffusion plant and the associated uranium hexafluoride manufacturing plant and uranium metal foundry process large quantities of relatively pure uranium compounds. The major sources of radiation from such materials are thorium-protactinium–234, and beta-emitting daughters of uranium–238, concentrated in the ash produced during the fluorination process. Since the element uranium can be a physiological hazard only if it enters the body, the chemical toxicity of the uranium materials processed at the Paducah Plant overshadows any radiation danger from this element.

Uranium is a rather expensive metal, and thus the incentive to recover as much as is economically feasible is great. The added desire to protect the population and to maintain a wholesome relationship with neighboring communities and individuals makes it essential that the air be exhausted through filters, and all effluent waters be discharged at extremely low concentrations of uranium.

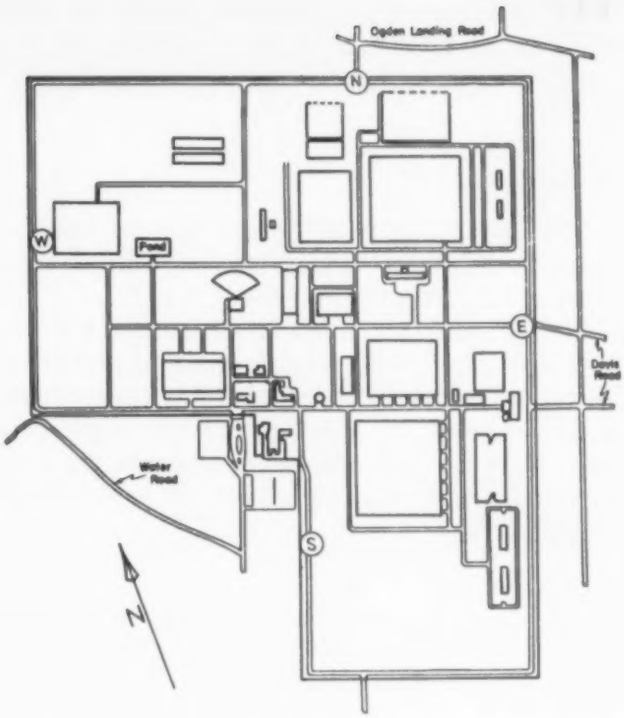

FIGURE 3.—AIR SAMPLING POSITIONS, PADUCAH GASEOUS DIFFUSION PLANT

Since no recovery process or filtering system is 100 percent efficient, the environmental monitoring program used to evaluate the effectivness of such measures consists of a continuing system for sampling air in four stations around the plant perimeter

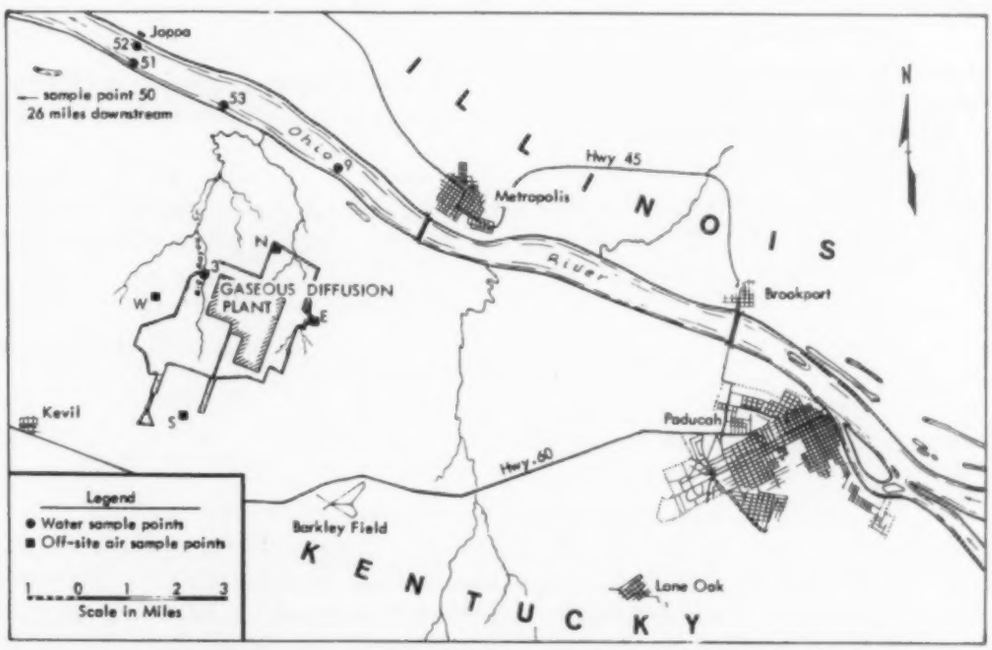

FIGURE 4.—WATER SAMPLING LOCATIONS, PADUCAH GASEOUS DIFFUSION PLANT

fence, and four off-site stations; and for sampling water at one location in Big Bayou Creek, and four locations on the Ohio River as shown in figures 3 and 4.

Discussion of Data

Data summarizing the environmental levels of radioactivity in the vicinity of the Paducah plant for 1962 are presented in tables 7, 8, and 9.

During 1962, air samples were collected continously at each of the four air sampling stations at the plant perimeter fence and at four air sampling stations about one mile outside the plant perimeter fence. Samples are collected during a sampling period approximating a 168-hour week using a membrane filter.

TABLE 7.—RADIOACTIVITY IN AIR, ENVIRONMENT AROUND PADUCAH PLANT, 1962

[Concentrations in pc/m³]

Sampling location	Uranium alpha			Beta[1]		
	First half	Second half	Year	First half	Second half	Year
Plant perimeter						
N	0.13	0.13	0.13	8.3	12	10
E	0.10	0.10	0.10	11	6.0	8.3
S	0.07	0.07	0.07	5.5	5.1	5.1
W	0.06	0.06	0.06	6.0	6.0	6.0
One mile outside perimeter						
N	0.06	0.07	0.07	5.5	6.0	6.0
E	0.05	0.08	0.07	5.5	5.1	5.0
S	0.06	0.06	0.06	5.5	5.5	5.5
W	0.05	0.05	0.05	5.5	4.6	5.1

[1] Interpreted as thorium-protactinium-234.

The average uranium analysis of the 417 air samples collected during the year 1962 was 3.7% of the envirnomental MPC for uranium, and the mean beta count of 418 air samples collected during the year was 0.6% of the MPC for thorium-protactinium-234, the daughter products of uranium-238.

TABLE 8. RADIOACTIVITY IN WATER, ENVIRONMENT AROUND PADUCAH PLANT, 1962

[Concentrations in pc/liter]

Sampling location	Uranium			Beta[1]		
	First half	Second half	Year	First half	Second half	Year
Big Bayou Creek 8	10	14	12	200	200	200
Ohio River 9	1	<1	<1	100	100	100
Composite of 50, 51, 52, and 53	1	<1	<1	100	100	100

[1] Interpreted as thorium-protactinium-234.

The average uranium analysis for 52 water samples collected from the Big Bayou Creek during the year 1962 was about 0.06% of the MPC for uranium, and the beta average was 1% of the MPC for thorium-protactinium-134. The average beta analysis for 12 samples collected below the plant in the Ohio River for the year was 0.5% of the daughter products of uranium-238.

TABLE 9.—EXTERNAL GAMMA RADIATION LEVELS, PADUCAH PLANT, 1962

[mr/hr]

Sampling locations	First half	Second half	Year
Plant Perimeter			
N	0.02	0.02	0.02
E	0.03	0.02	0.03
S	0.02	0.02	0.02
W	0.02	0.02	0.02
One Mile outside perimeter			
N	0.02	0.02	0.02
E	0.02	0.03	0.02
S	0.02	0.02	0.02
W	0.02	0.02	0.02

External gamma radiation in the vicinity of the Paducah plant averaged 0.02 mr/hr for the year.

Period	*Issue*
1959 and first quarter 1960	*December 1960*
Second and third quarters 1960	*March 1961*
Fourth quarter 1960	*July 1961*
First and second quarters 1961	*January 1962*
Third and fourth quarters 1961	*August 1962*

Reported Nuclear Detonations

August 1963

Three nuclear detonations were announced by the Atomic Energy Commission for the month of August 1963. These were low yield tests conducted underground at the Nevada Test Site on the twelfth, fifteenth, and twenty-third of the month. (Low yield range has been announced as less than 20 kilotons yield.) *Radiological Health Data* has assigned the following reference numbers according to test dates: 108, 109 and 110.

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UNITS AND EQUIVALENTS

Symbol	Unit	Equivalent
Bev	billion electron volt	
cpm	count per minute	
dpm	disintegration per minute	
g	gram	
kg	kilogram	1 kg = 1000 gm = 2.2 pounds
km^2	square kilometer	
kvp	kilovolt peak	
m^3	cubic meter	1 m^3 = 1000 liters
ma	millampere	
mas	milliampere-second	
Mev	million electron volts	
mi^2	square mile	
ml	milliliter	
mm	millimeter	
mrad	millirad	
mrem	millirem	
mr/hr	milliroentgen per hour	
mμc	millimicrocurie	1 mμc = 1 nc
nc	nanocurie	1 nc = 1000 pc = 1 mμc = 10^{-9} curies
nc/m^3	nanocurie per square meter	1 nc/m^3 = 1 $mμc/m^3$ = 1,000 $μμc/m^3$ = 1 mc/km^2 = 2.59 mc/mi^2
pc	picocurie	1 pc = 1 μμc = 10^{-12} curies
r	roentgen	
μμc	micromicrocurie	1 μμc = 2.22 dpm

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr′ a
10^{9}	giga	G	jĭ′ ga
10^{6}	mega	M	mĕg′ a
10^{3}	kilo	k	kĭl′ o
10^{2}	hecto	h	hĕk′ to
10	deka	da	dĕk′ a
10^{-1}	deci	d	dĕs′ ĭ
10^{-2}	centi	c	sĕn′ tĭ
10^{-3}	milli	m	mĭl′ ĭ
10^{-6}	micro	μ	mī′ kro
10^{-9}	nano	n	năn′ o
10^{-12}	pico	p	pē′ co
10^{-15}	femto	f	fĕm′ to

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